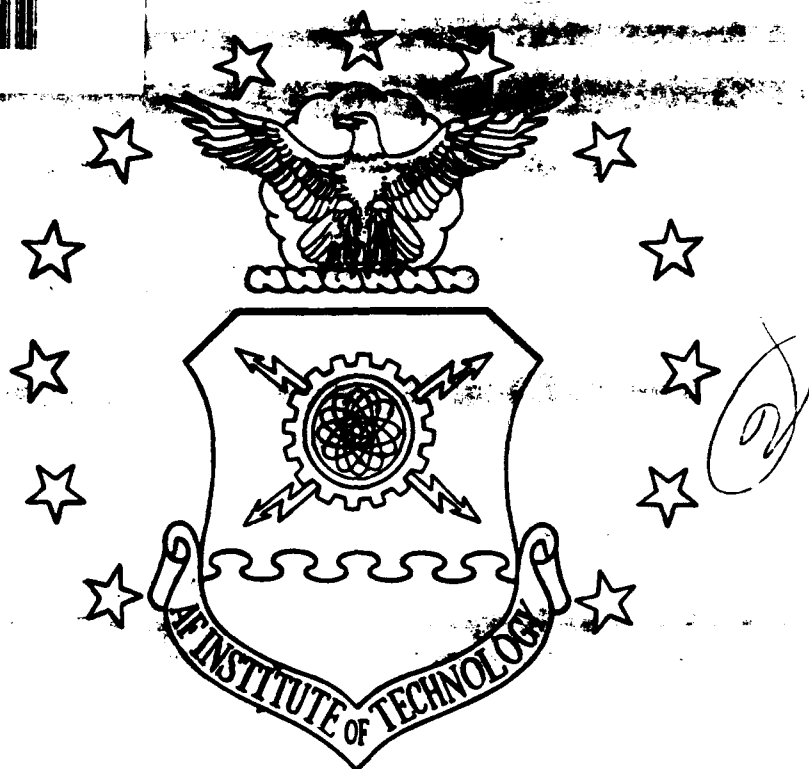


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GUIDANCE FOR THE DEVELOPMENT OF
AIR FORCE
STORM WATER SAMPLING PROGRAMS

THESIS

Jerry K. Weldon II, Captain, USAF
Roy T. Willis

AFIT/GEE/ENV/93-18

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STORM WATER SAMPLING PROGRAMS
THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
Air University
In Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Engineering and Environmental Management

DTIC QUALITY IS ASSURED

Jerry K. Weldon II, B.S.

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September 1993

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Jerry K. Weldon II

Roy T. Willis

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Abstract

The purpose of this research was to develop sampling guidance that will enable AF installations to conduct cost effective storm water sampling in accordance with current storm water regulations.

Data on the techniques used by AF bases to obtain storm water samples for the AF group storm water permit application were collected and analyzed. This information was used to outline management and resource requirements associated with implementation of NPDES storm water regulations. The use of in-house personnel, automatic sampling equipment, or a contractor to perform the field data collection was examined. An in-house manual approach to storm water sampling was identified as the preferred alternative. Also discussed are fundamental elements of storm water sampling which must be addressed to successfully complete the sampling process. Key elements presented include: personnel, mobilization strategy, sampling techniques, and equipment.

A case study was performed using data obtained from Altus AFB. The study demonstrates how matrices and simple mathematical modeling can be used to petition a permit authority for a reduction in the number of outfalls which require sampling analysis. Of the five outfalls at Altus AFB, only three were found to be in need of sampling.

**GUIDANCE FOR THE DEVELOPMENT OF
AIR FORCE
STORM WATER SAMPLING PROGRAMS**

I. Introduction

This chapter introduces the research problem and presents specific objectives of this study. Current Congressional legislation and Environmental Protection Agency (EPA) policy is presented to illustrate how the management of nonpoint source pollution is applicable to the United States Air Force. Also included in Chapter I are the scope and limitations of the research. Definitions of key terms are provided in Appendix A.

Clean Water Act

The framework for federal control of water pollution began in 1972, with the enactment of the Federal Water Pollution Control Act. Amended and renamed the Clean Water Act (CWA) in 1977, the focus of the nation's water pollution control efforts became the reduction of pollutants discharged into the nation's waterways. The CWA established a national goal to eliminate the discharge of pollutants into the navigable waters of the United States. This objective was to be achieved by controlling the discharge of pollutants from point sources using the National Pollutant Discharge Elimination System (NPDES) (Imhoff, 1989:1-3). The regulators believed

that if point sources of pollution could be sufficiently treated, then water quality within receiving waters could be maintained.

NPDES for Point Sources

The original NPDES permit system performs two basic functions in the CWA regulatory process. It sets specific limits on the amount of each pollutant a point source can discharge into a receiving body of water. It also requires the discharger to report failure to meet those levels to the appropriate agency (Arbuckle, 1992:99).

Title VI of the CWA assigns the EPA responsibility to administer financial grants to state and local agencies for the construction of wastewater treatment facilities. Between 1974 and 1988, federal grant and private industry wastewater treatment facility construction totaled approximately \$200 billion. These facilities were designed for pollution abatement and control of point sources (Novotny and Bendoricchio, 1989:400).

EPA conducted studies in the 70's and early 80's to assess the success of this massive water pollution control program. The water quality research revealed that, while significant progress had been made to control water pollution, desired water quality goals would never be achieved without a national effort to regulate nonpoint source (NPS) pollution (U. S. Congress, 1990:47991). The EPA estimates that nonpoint sources of pollution, such as agricultural and urban storm water runoff, account for at least thirty-three percent of all contamination in lakes and estuaries (Goldberg, 1993:27).

NPDES for Nonpoint Sources

The Water Quality Act of 1987 amended the CWA and created the National Pollutant Discharge Elimination System (NPDES) for Storm Water Discharges. As a storm water permit program to control NPS pollution, the new NPDES regulations require permits for storm water discharges from industrial activities; municipal storm sewer systems servicing populations over 100,000; and any activity with pollution discharges that contributes to a violation of a water quality standard (U.S. Congress, 1990:47992). All Air Force installations, as contributors of pollutants and/or industrial activities, have full responsibility to comply with the storm water NPDES program.

Under the NPS NPDES permitting process, the Air Force submitted a group application to the EPA on October 1, 1992. After the application is approved by EPA, each state water quality office will issue individual NPDES storm water permits to Air Force installations within its jurisdiction. The permit will require each installation to identify storm water outfalls, perform periodic sampling to demonstrate permit compliance, and develop a nonpoint source pollution management program.

To meet current regulatory requirements, Air Force installations must conduct cost effective and accurate storm water sampling. Inaccurate and unnecessary monitoring can easily become time consuming and costly. In addition, a storm water management plan based on erroneous data can result in noncompliance or unnecessary expenditures.

Specific Problem

The purpose of this research was to develop a storm water sampling guide that will allow Air Force installations to conduct cost effective storm water sampling in accordance with NPDES permit guidelines.

Investigative Questions

There were a number of questions that required investigation to solve the research problem:

- 1) What are the applicable federal and state rules and regulations governing storm water runoff at USAF installations?
- 2) What are the current sampling practices being used by AF NPDES Part 2 group applicants and other civilian group applicant programs throughout the U.S.?
- 3) What sampling alternatives can be implemented to ensure effective NPDES permit compliance?
- 4) What strategies and management practices can be implemented to reduce long-term sampling costs?
- 5) What methodology can be used by base-level environmental managers to establish a cost-effective sampling program that meets EPA guidelines?

Scope

This study will establish a guide by which Air Force bases can develop a long-term storm water sampling program that will comply with NPDES permit requirements. Issues addressed by the research include sampling techniques, the use

of in-house personnel versus automatic samplers versus contracted labor, and methods to petition a permit authority for the reduction in total sampling required. Current sampling programs used by AF installations were reviewed. Sampling protocols used in submittal of Part 2 of the USAF NPDES Group Application were the focal point of the review. Ensuring that the sampling protocol developed would comply with the Code of Federal Regulation's and state storm water sampling requirements was also a major focal point of the research.

EPA-acceptable methods to reduce total sampling requirements at an AF installation were investigated. Any method used had to meet standards established by the EPA. Storm water runoff prediction models were reviewed, as possible sources of data, to augment EPA-accepted methods to justify a reduction in NPDES permit sampling requirements.

Limitations

It is not the intent of this study to evaluate procedures or quality control measures used in laboratory water quality analysis. Field investigation was not used to validate a sampling technique or program. Storm water data used in this study was limited to sampling results provided by installations involved in the Part 2 NPDES submittal.

This study will not address impacts of NPS pollution on groundwater. NPS pollution from activities such as agriculture, agriculture, or mining were not considered, because these activities were not considered to be representative of a

typical Air Force base. Methods or best management practices for NPS pollutant reduction or control will not be addressed within this study.

II. Literature Review

This chapter will examine current literature on nonpoint source (NPS) pollution. The review is intended to describe the important relationship between storm water runoff and nonpoint source pollution. The review provides an insight into how the management of NPS pollution is applicable to the U. S. Air Force. A legislative history is presented to illustrate how the management of NPS pollution has evolved. The review concludes with a comprehensive summary of the permit application and compliance requirements dictated under the National Pollutant Discharge Elimination System (NPDES) for Storm Water Discharges.

Definition of Nonpoint Source Pollution

NPS pollution is defined as pollution that does not originate from a single point or operation. NPS pollution is generally associated with runoff water from the surface which carries with it sediment, organic material, nutrients, and toxins into receiving waters (Florida Department of Environmental Regulation, 1988:1-1). Pollution from nonpoint sources can be man-made or natural. Human activities introduce artificial levels of sediment and chemicals into waterways; natural sources occur as a result of erosion, decay of vegetation and dead animals, and other biological activity (Novotny and Chesters, 1981:5).

The discharge of NPS pollution into a receiving body of water is usually related to rainfall events and geological conditions. The diffuse manner and uncontrolled intervals that NPS discharges are released into surface waters add to the complexity of NPS pollution (Novotny and Chesters, 1981:6).

Water resources have experienced degradation as a result of human activities such as farming, mining, transportation, and urban development. In response to this growing problem, the United States has focused its attention on water quality improvement and conservation. As a result of this increased awareness, NPS pollution has been identified as a major contributor to water quality degradation. According to the EPA's 1989 report, Nonpoint Sources: Agenda for the Future, "environmental damage in 76 % of impaired lakes, 65 % of impaired stream miles and 45 % of the square miles of impaired estuaries are attributable to nonpoint sources of pollution" (Roy, 1991:66).

NPS pollution, as stated earlier, results from a variety of activities that take place over a wide geographic area. The EPA groups the primary sources of NPS pollution into the following seven categories:

Agriculture. About 50 to 70 percent of the nation's surface waters are affected by agricultural runoff which carries animal wastes, pesticides, and sediment (top soil).

Urban runoff. Affecting 5 to 15 percent of the nation's surface waters, urban storm water runs off buildings, industrial sites, streets, and parking lots carrying with it oil, grease, lead, fertilizers, and other toxic materials.

Hydromodification. About 5 to 15 percent of the waters are impacted by activities such as stream channelization, reservoir construction, flood prevention or lake drainage.

Resource extraction. Mining affects from 1 to 10 percent of the nations waters from abandoned mines, sealed wells, and mining waste piles that contain mine tailings. Water pollution from active mines is considered point source pollution.

Silviculture. About 1 to 5 percent of surface waters are harmed by logging operations which results in erosion from forests where soil has been disturbed.

Construction. About 1 to 5 percent of surface waters are affected by construction site runoff carrying sediment, chemicals, and debris.

Land disposal. Leachates from septic tanks or landfills and land application of sewage sludge impact 1 to 5 percent of the nation's surface waters. (U.S. GAO, 1990:8,9)

Air Force installations contain pollution sources which fall into the urban runoff category. A two year study conducted at Grissom AFB, Indiana, assessed the environmental impact of Air Force land use activities on storm water. The final report noted that the scope of three watershed experiments conducted at the base were "very similar" to other urban NPS studies. The authors stated, "Each watershed has a high degree of imperviousness (20 to 25 percent) which is characteristic of urban areas" (Overton and others, 1980:31). Drainage ditch and storm sewer systems were also cited as urban-type characteristics found at Grissom AFB (Overton and others, 1980:6). To effectively control NPS pollution and comply with NPDES

permit requirements, it is important for Air Force managers to understand the components and characteristics of urban sources of NPS pollution.

Sources of Urban NPS Pollution

The identification of actual sources of urban NPS pollution is an essential step toward controlling the adverse effects of urban storm water runoff. It is possible to correlate certain types of pollutants to certain activities in an urban environment. Urban rainfall is generally acidic with pH values below 5 pH units. The elevated acidity of urban precipitation damages, erodes, or dissolves pavements and building materials. The wind is a source of particles that may originate from distant or local sources. Litter is a source of materials such as cans, broken glass, vegetation residues, and pet wastes. "Street dirt" represents the bulk of the street surface accumulated pollution. The sources of street dirt include road deterioration, vegetation residues, pet and other animal wastes and decomposed litter (Imhoff and others, 1989:50).

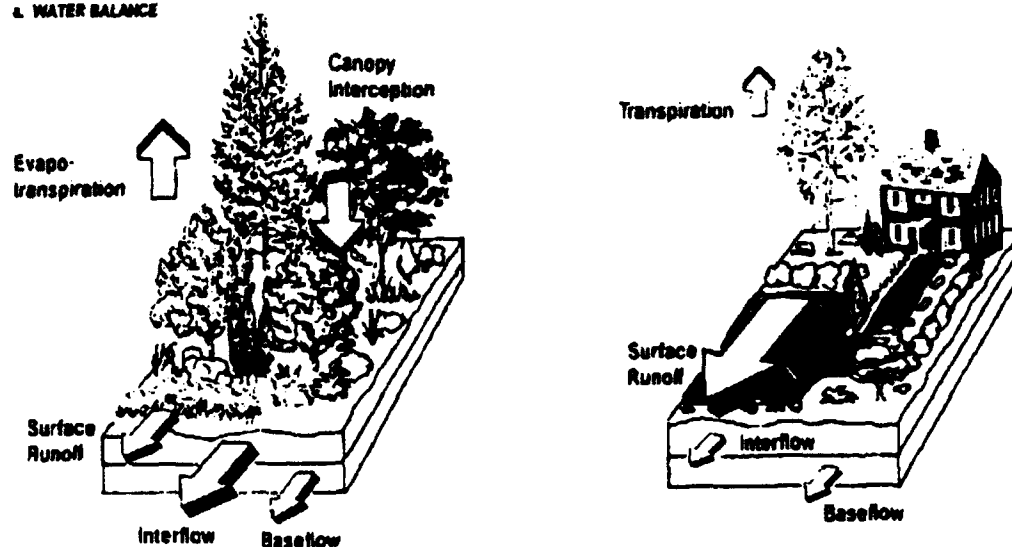
Traffic emissions are responsible for some potentially toxic pollutants found in urban runoff, including lead, chromium, asbestos, copper, hydrocarbons, phosphorous, zinc, and nickel. Road deicing salts that are applied in winter to maintain streets cause highly increased concentrations of salts in the urban runoff (Imhoff and others, 1989:51-52).

Characteristics of Urban NPS Pollution

Storm water runoff from urban areas has two distinct characteristics: large volumes of water and high concentrations of pollutants. The first characteristic of urban runoff is due to the large impervious surface area found in urban areas. Large impervious surface will result in a large volume of water runoff. The hydrology of a watershed is transformed during urbanization. Trees, natural depressions, and ground cover that provide a natural storage capacity by absorbing rainfall are removed. Rooftops, roads, parking lots, and sidewalks make much of an urban area impervious to rainfall (Schueler, 1987:1.1). Unable to percolate into the soil, rainfall is almost completely converted into runoff. Urban areas typically discharge larger volumes of storm water than nonurban areas. The increased velocity and flow rate create an effective means of transporting polluting materials from the land surface to receiving waters (Walesh, 1989:67-68). The net effect of urban development, increased peak discharges, increased volume of storm water runoff, and increased runoff velocity, is depicted in Figure 1.

The pollutants that accumulate on impervious surfaces, such as streets and rooftops, are more highly concentrated than in non-urban areas. Urban storm water contains concentrations of several pollutants that either meet or exceed the levels normally found in raw municipal and industrial sewage. High levels of biochemical oxygen demand (BOD), suspended solids, toxic materials (lead, oil, and other hydrocarbons) and bacteria characterize nonpoint source pollution from urban areas (Walesh, 1989:67-68).

a. WATER BALANCE



b. STREAMFLOW

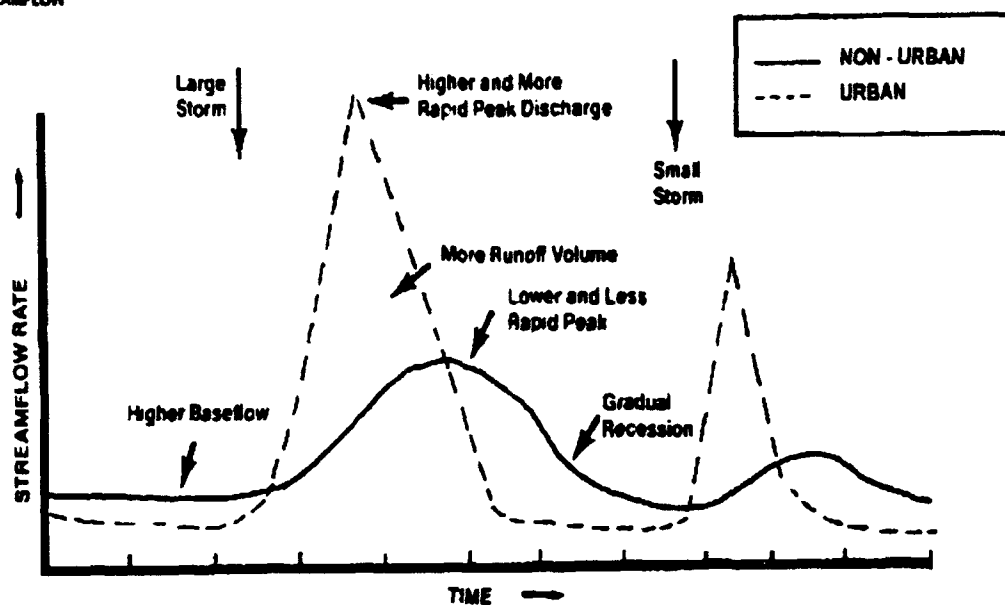


Figure 1. Watershed Hydrology as a Result of Urbanization (Schueler, 1987:1.3)

A San Jose, California, project compared the urbanized portion of Coyote Creek to non-urbanized sections of the creek. The project analyzed the pollutants

which associated with particulates that settle into the creek-bed sediment as storm water is transported down stream. The results of this project are shown in Table 1. The study revealed that urban sediment contained higher peak levels of BOD, lead, arsenic, and phosphates.

Table 1
Characteristics of Storm Water Runoff (USEPA, 1990:11)

CONSTITUENT (mg/kg of sediment)	URBAN	NONURBAN
BOD	1,900	925
Lead	400	40
Arsenic	13	1.5
Phosphates	6.7	1.8

Components of Urban NPS Pollution

In this section the elements of urban runoff that lead to the degradation of rivers and lakes are discussed. The problem components in urban storm water runoff are oxygen depleting matter, solids, pathogens, and toxics.

Oxygen Depleting Matter. One of the most important qualities of water is the dissolved oxygen (DO) content. Oxygen in water supports aquatic life and prevents anaerobic conditions. The importance of dissolved oxygen has made oxygen depleting matter the most studied nonpoint source pollutant. Researchers have found, during low flow periods following storms, that the DO depletions are about the same as caused by the dry weather discharges of biochemical oxygen demand (BOD) from municipal waste

water treatment plants. BOD is the method used to measure dissolved oxygen consumption. During peak flow periods, storm discharges increase BOD loading on the receiving waters to about 10 times greater than low flow (USEPA, 1990:8).

Because a large percentage of oxygen demanding materials in nonpoint source runoff is associated with floatable and settleable solids, the BOD in urban storm runoff is exerted over a longer period of time than other types of wastewater discharges. The long term DO depletion from nonpoint source discharges is not completely understood and may actually be greater than indicated, based on conventional BOD mass balances (Field and Pitt, 1990:65). The BOD exerting sediments carried in storm water runoff can affect DO concentrations in a receiving water body for days or even weeks after a storm. The previously mentioned San Jose project found that urban runoff affecting Coyote Creek exerted increased oxygen demand 10 to 20 days after a rain event, rather than during the first few days after a rain event (Field and Pitt, 1990:65-66).

Solids. Urban storm runoff quality depends on the relationship between solids and the pollutants that are deposited on impervious surfaces between rainfall events. A 1972 EPA report on water pollution aspects of street surface contaminants found that the very fine fraction of solids on street surfaces "was only 6% of the total by weight, but with it was associated about 25% of the oxygen demand, over 50% of the heavy metals, and nearly 75% of the pesticides" (Collins and Ridgway, 1980:159). Storm water runoff transports solids in three forms; suspended, dissolved, and large debris. The suspended solids found in runoff are, by definition, the portion of total solids that can be removed by a membrane filter with a pore size of about 1.2 μm . The dissolved

solids consist of both organic and inorganic molecules that are soluble (in true solution) in water. Examples of large debris include tree branches, tires, and lumber.

The impact of land use and related nonpoint source pollution on Lake Austin located near Austin, Texas, was studied from 1986-1988. The study concluded that increased impervious surfaces associated with urban development directly contributed to increases in the total suspended solids in the lake (Todd and others, 1989:646-647).

Samples taken from a rural watershed and an urban watershed during the same rainstorm in east central Wisconsin demonstrate the relationship between impervious surface, runoff flowrate, and sediment yield. Table 2 reflects the peak flow and unit sediment yield for the two watersheds after receiving 0.87 inches of rainfall in 5 hours.

Table 2

Runoff Response of Rural and Urban Watersheds
Subjected to the Same Rainfall Event (Walesh, 1989:70)

Characteristic	URBAN	RURAL
Area (km ²)	2.90	3.74
Impervious Surface (%)	65.1	5.7
Point Sources	None	None
Peak Flow (ft ³ /sec)	16.8	0.064
Suspended Sediment (lb/acre)	2.56	0.0071

The urban watershed responded with much greater peak flow and sediment yield, demonstrating the significant impact urban areas can have on the movement of NPS pollution to a receiving body of water (Walesh, 1989:69).

There are several case studies that demonstrate the correlation between urban runoff suspended solids and pollution transport. Data collected during a study of urban storm runoff quality in southeast Michigan suggest that there is a correlation between suspended solids and other contaminants. The researchers were able to show that total organic nitrogen, total phosphorous, total lead and total iron are all related to the mass of suspended solids in storm water runoff (Collins and Ridgway, 1980:160-161). A study near Champaign-Urbana, Illinois, revealed that sediments in an urban stream contained lead concentrations of almost 400 ppm. The study noted that 80 percent of the lead detected was associated with suspended solids (Rolfe and Reinhold, 1977:25). Studies on the Saddle River near Lodi, New Jersey, found a correlation between sediment content in urban runoff and heavy metal concentrations of zinc, copper, lead, chromium, and cadmium (Wilbur and Hunter, 1980:47).

Salts applied during winter months to remove ice and snow from runways, roads, parking lots, and sidewalks are a significant source of dissolved solids in runoff. Several types of deicers are used including sodium chloride, calcium chloride, urea, and calcium magnesium acetate (CMA). Sodium chloride, usually in the form of rock salt, is the most widely used deicer (Hanneman, 1992:431). Due to its extreme solubility, almost all the chloride applied for snow removal is transported in runoff to surface or ground waters. Researchers have established a correlation between road salting and

elevated chloride levels in surface waters. A study of chloride concentrations in snowmelt runoff from an urban catchment basin, attributed concentrations up to 18,200 mg/l to road salting. The research concluded that roadway runoff is "salt-polluted", carrying deicing salts in solution (Jones and Jeffrey, 1992:35).

Airports also contribute to the wintertime use of deicing chemicals with their practice of aircraft and runway deicing. Ethylene glycol is the principal aircraft deicer and urea is used in runway deicing. Ethylene glycol is a concern in runoff because concentrations of 1 percent and 0.1 percent exert a BOD of roughly 5,000 mg/l and 500 mg/l, respectively. Urea is a concern in runoff because of its toxic degradation products, ammonia and nitrate. Monitoring studies at Michigan airports have documented evidence of adverse water impacts from deicers in runoff. The BOD in one airport's storm water was 6,900 mg/l and was accompanied by an ethylene glycol level of 7,200 mg/l (Sills and Blakeslee, 1992:331). Ammonia levels in runoff are commonly found to be in the 2 to 15 mg/l range, which greatly exceeds criteria levels established to protect surface water aquatic life. For example, Michigan has established ammonia criteria levels to protect aquatic life at 0.4 mg/l for acute exposure and at 0.20 mg/l for chronic exposure (Sills and Blakeslee, 1992:329). Nitrate and nitrite levels were also frequently found excessive at airports studied. Maximum reported values for airports ranged from 0.85 to 58 mg/l (nitrate) and 0.12 to 8.88 mg/l (nitrite) (Sills and Blakeslee, 1992:331).

Storm water also conveys large debris to receiving water that detracts from the aesthetics of the area. This material will disperse, float, or wash ashore creating odor problems and detracting from general appearance (USEPA, 1990:9).

Pathogens. Nearly every urban and suburban land use exports bacterial levels in undiluted storm water runoff that exceeds public health standards for water contact recreation (Schueler, 1987:1.6). Bacteria such as the fecal coliform that is measured in point source discharges exists in NPS pollution. A major health concern with urban runoff is the very high concentration of coliform bacteria and other pathogens in storm water (Imhoff and others, 1989:50). One study found that the bacterial content of urban storm water was two to four orders of magnitude greater than the concentrations considered safe for swimming and other water recreation activities (Field and Pitt, 1990:65).

Toxics. Toxicity problems in water bodies can result from minute discharges of heavy metals, pesticides, or persistent organics. Long-term effects may be exhibited on the environment as these substances gradually accumulate in aquatic species (USEPA, 1990:9). Urban runoff has long been identified as a significant source of toxic pollutants.

Toxic levels in fish living in the receiving waters have been an excellent indication of both the short term and long term effects of heavy metals and chemicals discharged into water. Fish kills reflect short term loadings, while bioconcentration of chemical compounds in fish tissue indicate the long term hazards associated with toxic water pollutants (Field and Pitt, 1990:65). Bioconcentration occurs when the chemical

compounds stored in the fatty tissue of fish are passed up the food chain in successively higher concentrations. The danger of these compounds, such as heavy metals and pesticides, is that they usually exist in dissolved concentrations that are too low to detect in a water sample, but they can bioaccumulate in fish at levels that are toxic or carcinogenic to humans. Table 3 summarizes the relative contribution of urban runoff to heavy metal loading into New York Harbor.

Table 3

**Metals Discharged in Harbor from New York City Sources
(Field and Turkeltaub, 1981:93)**

Source	Copper lb/day	Chromium lb/day	Nickel lb/day	Zinc lb/day	Cadmium lb/day
Plant Effluents	1,410	780	930	2,250	95
Runoff**	1,990	690	650	6,920	110
Untreated Wastewater	980	570	430	1,500	60
Average Concentrationmg/L	0.25	0.12	0.11	0.62	0.015

* - In reality, shockload discharges are much greater.

- Runoff data includes separate storm sewer drainage and wet-weather combined sewer overflows (CSO).

In 1988, the Ohio River Valley Water Sanitation Commission (ORSANCO) examined fish tissue samples to determine the presence of chemical compounds that bioaccumulate. The purpose of the study was to determine toxic loading in the Ohio

River from NPS pollution. Any chemical detected was compared to those quantities discharged from regulated point sources. The results of the program indicated that urban runoff is a significant source of toxins. The fish tissue analysis revealed concentrations of polychlorinated biphenyls (PCBs) and chlordane which exceeded fish tissue criteria used to regulate interstate commerce. As a result, Pennsylvania, Ohio, West Virginia, Kentucky, and Indiana each issued advisories against the consumption of certain fish taken from the Ohio River (Norman, 1991:44-46).

Legislation and Policy

Increased awareness of NPS pollution occurred when the quality of our nation's surface waters failed to meet the Clean Water Act's water quality goals despite extensive, and largely successful efforts, to control point source pollution. This inability to achieve the stated objectives of the Act led to extensive research into the impact of NPS pollution. The National Water Quality Inventory, 1988 Report to Congress provided a general assessment of water quality based on reports submitted by states in accordance with the Clean Water Act. The report concluded that "pollution from diffuse sources, such as runoff from agricultural, urban areas, construction sites, land disposal and resource extraction is cited by the States as the leading cause of water quality impairment" (U.S. Congress, 1990:47991). This assessment and earlier research identified the significant causes and impacts of NPS pollution. The realization that significant water quality problems are now due to NPS

pollution has led to legislative action within Congress to improve the situation. This section will review the legislative history of NPS pollution control.

Pre-Clean Water Act. Prior to 1972, most legislation regarding the control of nonpoint source pollution was related to resource protection and development and land management policy. In the late 19th century, the federal government established programs to control and influence water resource development in the form of navigation, river development, dams and flood control, and irrigation. In the process, several federal agencies responsible for water resource development and pollution control were created: the U.S. Army Corps of Engineers, the Federal Power Commission (a part of the present Department of Energy), and the Federal Water Pollution Control Administration in the Department of Interior (predecessor of the U. S. Environmental Protection Agency). It is the efforts that these agencies made between 1938 and 1970, that led to the beginning of nonpoint pollution control. During this time frame, four "Flood Control Acts" were adopted by Congress to minimize and reduce floods. Storm water events produce both flooding and nonpoint source pollution discharge into waterways. Therefore, any effort to control flooding would simultaneously impact nonpoint source pollution discharge. Floodplain management during these years would produce regulations at the local and state level that were actually reducing nonpoint source pollution (Novotny and Chesters, 1981:17).

Federal Water Pollution Control Act, 1972. In 1972, the Federal Water Pollution Control Act was passed to regulate discharge from point sources. This

legislation and the programs it generated proved to be only of partial success in curbing water pollution (Griffin, 1991:6). Under the Act, the Nationwide Pollutant Discharge Elimination System (NPDES) program was created as a water quality control enforcement program to be directed by the Environmental Protection Agency (EPA).

The Act prohibited the discharge of any pollutant to navigable waters from a point source unless the discharge was authorized by a NPDES permit. Storm water runoff was a notable exception. Attempts were made between 1973 and 1976 to include NPDES permit requirements for storm water, but no significant legislation was passed (Oakley and Forrest, 1991:53). Large sums of money were spent by municipalities throughout the U.S. to abate point source pollution. "Nationwide, the cost of point source cleanup between 1974 and 1988 was approximately \$200 billion" (Novotny, 1989:400).

Clean Water Act, 1977. In 1977, Congress first recognized NPS contributions to water pollution and began to regulate it. Section 208 of the Act specifically addressed the need to control NPS pollution (U.S. Congress, 1987:95-217). The Act also fostered the National Urban Runoff Program (NURP), which was conducted between 1978 and 1983. The program received funding from the EPA and was designed to characterize storm water discharges from residential, commercial, and light industrial areas. Studies were conducted at twenty-eight cities across the country and the findings were an important element in the development of storm water regulations. The data indicated significant levels of pollutants in every category that

point source discharge was regulated. Some pollutants such as sediment and toxics were consistently found in levels that greatly exceeded accepted levels (Oakley and Forrest, 1991:52).

Water Quality Act, 1987. The Water Quality Act of 1987 established the basis for the current NPS pollution control program. This Act was a reauthorization of the CWA which called for "all 50 states ... to conduct surveys and develop assessment reports defining the nature and extent of NPS pollution within their boundaries" (Griffin, 1991:8). As a result of this Act, NPS pollution will be regulated under the National Pollutant Discharge Elimination System (NPDES).

Section 402(p) was added to the Act to address storm water. In summary, the new section states that the EPA can require NPDES permits for storm water discharges associated with industrial activity; large municipal separate storm water systems (systems serving a population of 250,000 or more); discharges from medium municipal separate storm water systems (systems serving a population of 100,000 or more); and discharges that the permitting authority determines contributes to a violation of a water quality standard or is a significant contributor of pollutants to the waters of the United States (USEPA, 1991a:iv).

Federal, state, and other public agencies have full responsibility to comply with the NPDES permitting process. In May of 1987, Mr. Gary Flora, USAF/LEE, stated in a letter to all Major Command Civil Engineers, "Major commands should identify NPS pollution problems on their installations ... and have NPS pollution

control programs in place ..." (Flora, 1987:1). This policy letter established the requirement for NPS pollution management programs at Air Force installations.

All states have in place a program to address storm water, erosion, and sediment control as a result of 33 USC 1329 of the Water Quality Act (Seaman, 1990:12). The WQA of 1987 also authorizes federal loans and grants to help state, local governments, conservation districts, farmers, foresters, and businesses manage sources of NPS pollution. Under the Act, the EPA is responsible for reviewing and approving state plans and preparing an annual report to Congress (Roy, 1991:66). States are required to report to the EPA every two years on their progress toward meeting the Clean Water Act's water quality goals (Water Quality 2000: Phase II, 1990:48). Land development programs have been initiated as well as agricultural pollution abatement programs throughout the nation.

NPDES for Storm Water Discharges

On December 7, 1988, EPA issued the proposed NPDES program for storm water discharges. After reviewing over 3000 pages of comments from Congress, municipalities, and industries (Oakley and Forrest, 1991:53), the NPDES storm water regulations were promulgated in the 16 November 1990 Federal register (55 FR 48062-48091) and are contained in 40 CFR parts 122, 123, and 124.

The new storm water NPDES permit application regulations specify two types of dischargers: municipal and industrial. Municipalities with a population greater than 100,000 comprise the municipal category. To be subject to the storm water

permit regulations, an industrial facility must fall within one of 11 categories specified in 40 CFR 122.26(b)(14)(i)-(xi). Five of these categories are defined relative to Standard Industrial Classification (SIC) codes. The six remaining are described descriptively. The eleven categories are listed in Appendix B. The program will require 173 cities, 47 counties, and an estimated 100,000 industries to apply for a NPDES permit (Oakley and Forrest, 1991:52). U.S. Air Force installations are classified in the industrial category.

The regulations establish permit application requirements for storm water discharges associated with municipal and industrial activity. The requirements for industrial activities are primarily contained in Section 122.26 of Section 40 of the Code of Federal Regulations (USEPA, 1991a:1).

Industrial Permit Application

The regulation specifically defines an industrial activity and describes four options that an industry can use to apply for a permit: an individual permit application; a group permit application; notification of intent to be covered by a general permit; or as part of a combined sewer system. Dischargers following the first three options are required to submit information, whereas industrial discharges to combined sewer systems are not required to obtain a permit (USEPA, 1991a:9). A flow diagram summarizing the permitting process is located in Appendix C.

An individual permit is the most simple of the three. It requires an applicant to conduct sampling for suspected pollutants; collect certain information such as major

drainage outfalls, an estimate of impervious area, and a description of significant materials usage; and fill out the necessary forms. The permit authority will review the application and develop an individual permit for the applicant. Following a public review period, a permit will be issued (Oakley and Forrest, 1991:55).

A group application has the advantage of being less expensive because of reduced sampling requirements, but it is much more complex administratively. The group permit is divided into two parts. Part 1 requires all members of the group to summarize the industrial activities they're involved in, to include the materials handled and materials management practices of each group member. The purpose of Part 1 is the same as the individual permit application: to identify potential sources of nonpoint source pollution, discharge conditions, and estimates of impervious area. Following EPA approval of Part 1, the group can proceed with Part 2. During Part 2, ten percent of the group members are required to conduct storm water sampling and submit the results to EPA headquarters. Part 2 of the group application is to contain quantitative information on the chemicals in the storm water, rainfall depth, rainfall duration, maximum rate of storm water runoff, and runoff volume. Note that even though there is a group application, there is no such thing as a group permit -- the data submitted by the group will be used by the EPA to develop a general permit for the group. Following a public review period, this model permit will be provided to the state or EPA region NPDES authorities. The state or EPA region will develop and issue a general or individual permit to group members within their jurisdiction (USEPA, 1991a:75).

The third option, application for a general permit, allows an industry to simply file a Notice of Intent (NOI) under provisions of a general permit that is prepared by the EPA. This type of application has the advantage of not requiring baseline sampling or site surveys. The industry will simply be held liable to the standards established by the general permit. The general permit will be promulgated in each non-NPDES State, following State certification, and will serve as a model for use by States with NPDES authority (U.S. Congress, 1990:48006). The state certification process is required by the Clean Water Act. The state is required to certify that the discharge limits established in the permit will comply with all limitations necessary to meet water quality standards established pursuant to any state laws or regulations (Arbuckle and others, 1992:97). The EPA intends general permits to provide baseline storm water management practices. There is more risk involved in this option since the general permit does not guarantee that all discharges generated by a particular kind of industrial activity will be allowed (Gormley, 1992:58). EPA proposed general storm water permit rules on August 16, 1991. As of September 3, 1992 two types of general permits were identified: one type covers construction sites disturbing 5 or more acres; the other encompasses "all other industrial activity." To participate in the general permit option an industry was required to submit a notice of intent before 1 October 1992 (Bishop, 1993:39). Industries not eligible for coverage under a general permit must file an individual or group permit application (U.S. Congress, 1990:48006).

State, Federal and other public agencies have full responsibility to participate in one of the four application options and comply with the NPDES permitting process. A permit that is issued to an individual or group applicant will not expire for five years. Enforcement of the permit will be the responsibility of the authority that issued the permit. The CWA provides that any person who violates a permit condition is subject to a civil penalty not to exceed \$25,000 per day of violation. Any person who willfully or negligently violates a permit is subject to a fine of not less than \$2,500 or more than \$25,000 per day of violation, or imprisonment for not more than one year, or both (Arbuckle, 1992:120).

The EPA has accepted an Air Force proposal to submit a group application. The Part 1 application for the 133 Air Force installations in the U.S. was submitted to the EPA on 22 March 1992. The EPA conditionally accepted Part 1 on 19 October 1992 and instructed the Air Force to proceed with the sampling requirements for Part 2. In order to comply with Part 2, the Air Force was required to collect quantitative sampling data from at least 10% of the installations and forward the information to the EPA. Fifteen bases accepted by the EPA as representative AF sampling bases for the Part 2 application are: Westover AFB, K.I. Sawyer AFB, Dover AFB, Keesler AFB, Homestead AFB, Scott AFB, Altus AFB, Vance AFB, Luke Waste Annex, Davis-Monthan AFB, Elmendorf AFB, Kaena Point SPS, Mt Home AFB, Minot AFB, and Fairchild AFB. Figure 2 below indicates the 15 Air Force bases and the EPA regions.

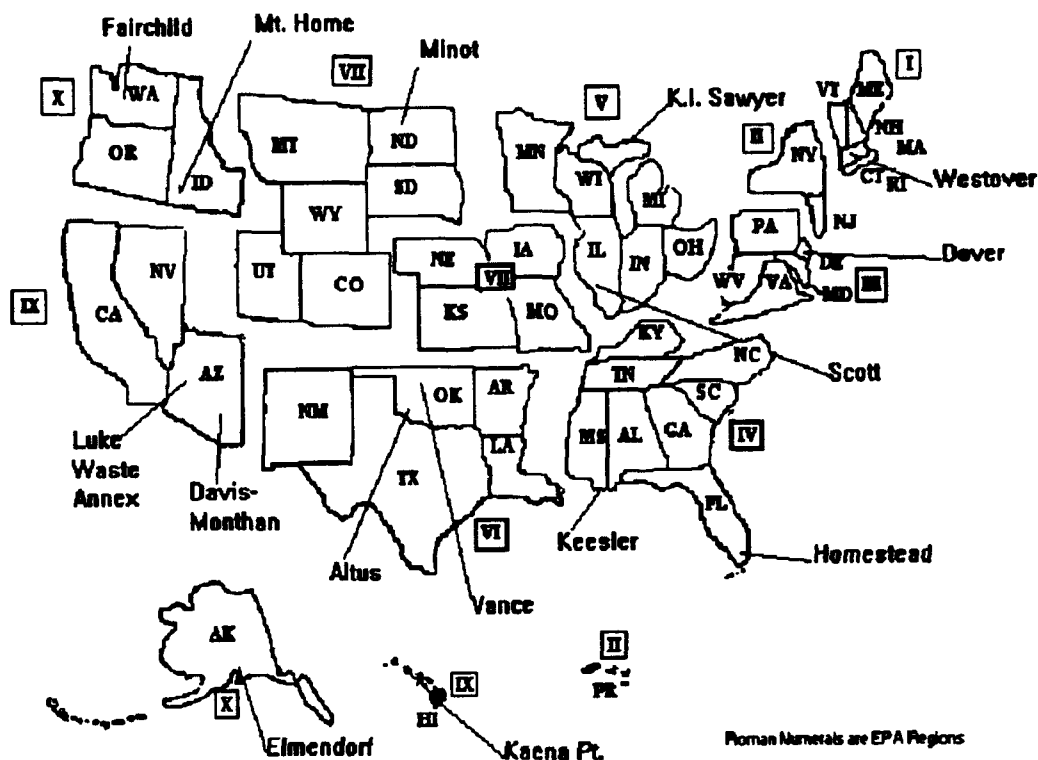


Figure 2. AF Part 2 Group Application Sampling Locations

Industrial Permit Requirements

After the permit application is approved by the EPA, each state or EPA region that has permit authority will issue individual NPDES storm water permits to installations within their jurisdiction. The Clean Water Act allows authorized states to administer the NPDES program instead of EPA. As of 1 June 1993, there were 25 states that had been granted permit authority from the EPA. A permit will require

each installation to develop a NPS pollution management program, identify storm water outfalls, and perform periodic sampling to verify permit compliance.

NPS Management Program. The NPS pollution management plan is required to minimize pollutants leaving the permitted site. Designed as a pollution prevention-type plan, installations are required to incorporate five major areas into their plan: (1) planning and organization; (2) assessment; (3) Best Management Practices (BMP) selection and plan design; (4) implementation; and (5) evaluation and site inspection. Other requirements include forming a pollution prevention team and annual site inspection and reporting (USEPA, 1992b:1).

Storm Water Outfall Identification. Each permit application must identify all storm water outfalls at the applicants installation. Once the permit is issued, each of these outfalls must be monitored and sampled as specified in the permit. The EPA has established a procedure for installations to petition for substituting identical effluents. As presented in 40 CFR 122.21(g)(7),

when an industrial applicant has two or more outfalls with substantially identical effluents, the permitting authority may allow the applicant to test only one outfall and to report the quantitative data that also apply to the substantially identical outfalls.

The authority that issues the permit will make the final determination of the methods acceptable to demonstrate that two separate outfalls are substantially identical. The EPA outlines three petition options in its NPDES Storm Water Sampling Guidance Document: 1) submission of a narrative description and a site

map; 2) submission of matrices; or 3) submission of model matrices. Each option must be certified by a professional engineer (USEPA, 1992a:106).

Narrative Description. This method of petition consists of a narrative description of the outfalls and a site map. The petitioner must demonstrate that two outfalls contain substantially identical storm water discharges. The narrative portion must include a description of the industrial activities and processes; materials that may be exposed to storm water; storm water and material management practices; and flow characteristics. A site map must also be included which details the outfall's drainage basin characteristics. Topography, drainage characteristics, past and present land uses, and the industrial activities, materials, and structural control measures described in the narrative must be identified on the map (USEPA, 1992a:106).

Matrices. The matrix method of petition contains the same information that is required in the narrative description, presented in a matrix format. With this method, the petitioner must demonstrate that the outfalls have discharges that meet the criteria established by the permitting authority. An example of how industrial activities and flow characteristics would be identified using a matrix is presented in Table 4.

Table 4

**Matrix Identification of Storm Water
Outfall Characteristic (USEPA, 1992a:114-115).**

Industrial Activities

OUTFALL	A	B	C	D
3	X	--	X	X
4	X	--	X	X

KEY: A = Outdoor storage of raw materials
 B = Fueling
 C = Waste materials storage (dumpster)
 D = Landfill activity

Storm Water Flow Characteristics

OUTFALL	A	B
3	0.2	3,500
4	0.2	2,900

KEY: A = Estimated runoff coefficient
 B = approximate drainage area (square feet)

Matrices presented to a permit authority might include significant materials exposed to storm water; storm water management practices; and areas where pesticides, herbicides, and fertilizers are applied.

Model Matrices. This method is designed to assist installations with a large number of storm water outfalls and the potential for numerous groupings of identical outfalls. Model matrices should contain information for one grouping of substantially identical outfalls. For example, if a facility has 150 outfalls and several

groupings of identical outfalls, the facility would choose one of the groupings of identical outfalls to provide information in the model matrices. The petitioner must demonstrate, using matrices, that all outfalls within this grouping have storm water discharges that meet the permitting authority's criteria for identification of identical outfalls (USEPA, 1992a:107).

Mathematical Modeling. The permit authority will make the final determination as to whether an applicant has sufficiently justified two outfalls as having identical effluents. The EPA storm water hotline and the EPA Region VI permit authority have suggested the use of storm water modeling to provide supplemental information to support the identification of similar outfalls. The EPA recognizes several modeling options for simulation of runoff quality in urban-type storm systems. The models range from simple (unit loads) to complex (computer-based buildup/washoff), though, some "simple" methods, such as the EPA statistical method, can incorporate sophisticated concepts (USEPA, 1991b:5).

Unit Loads. This manual model is based on the EPA Nationwide Urban Runoff Program (NURP) study and uses the event mean concentrations (EMC) from that study to predict total annual NPS pollutant loading for a given set of land uses (Praner and Sprewell, 1992:59). Annual loads are calculated by multiplying areas, typically in acres, by mass per area per time, typically lb/ac-yr, for various pollutants in the contributing area. The mass per area per time value is based on the land use EMC defined by the NURP or by an on-site concentration estimate; the

runoff coefficient of the land surface; and the average annual rainfall. All runoff is assumed to have the same, constant concentration for a pollutant (USEPA, 1991b:5).

Spreadsheet. Computer spreadsheet programs enhance the use of simple methods such as unit load modeling which rely on sets of coefficients and EMCs, which are functions of land use (USEPA, 1991b:29). The advantage of the spreadsheet is that a mixture of land uses, with varying concentrations, may easily be simulated. The relative contributions of different land uses within a single catchment area may be easily identified. The spreadsheet approach is best suited for the estimation of long-term loads, such as annual or seasonal, because very simple prediction methods generally perform better over a long averaging time (USEPA, 1991b:6).

Statistical Method. The EPA adopted this method also known as the "Simple Method," from Schueler (1987), as an acceptable method for estimating annual pollutant loads discharged from an urban area (USEPA, 1992c:5-13). Like the previous models, NURP data was used to develop the model. The primary difference between the statistical method and those previously discussed is due to the assumption of the statistical method that EMCs are distributed lognormally at a site. The concentrations may be characterized by their median value and by their coefficient of variation. The estimation of the whole EMC frequency distribution for a pollutant is a notable advantage of the Simple Method over unit load and simple spreadsheet applications (USEPA, 1991b:7). The Simple Method is primarily intended for use on urban sites less than a square mile in area. The method is considered precise enough

to make reasonable and reliable NPS pollution management decisions at the site-planning level. For example, it can be used to estimate the probability that pollutant concentrations will exceed a given threshold level (Schueler, 1987:1.10).

The Simple Method estimates urban storm pollutant export by solving the following equation:

$$L = [(P)(P_j)(R_v)/12](C)(A)(2.72);$$

where L = annual pollutant load (lbs);
P = rainfall depth (inches) over the desired time interval;
P_j = factor that corrects P for storms that produce no runoff;
R_v = runoff coefficient, which expresses the fraction of rainfall which is converted into runoff;
C = flow-weighted mean concentration of the pollutant in urban runoff (mg/l);
A = area of the development site (acres); and
12, 2.72 are unit conversion factors. (Schueler, 1987:1.10)

Regression. The U.S. Geological Survey (USGS) adopted this method also known as the "Nationwide Regression Equation (NRE)" model from Driver and Tasker (USEPA 1991b:7). The NRE model is useful for water quality management and planning and represents the best generalized regression equations currently available for urban runoff quality prediction (USEPA, 1991b:7). Combining USGS and EPA NURP urban storm-runoff data bases, a total of 2,813 storms for 173 urban stations in 30 cities in the U.S. were assembled for multiple regression analysis (Driver and Tasker, 1990:2). Two sets of regression models for storm water pollutant loading were developed, one to estimate storm-runoff loads and one to estimate mean annual loads (Driver and Tasker, 1990:6). The models were developed for the following constituents: chemical oxygen demand (COD), suspended solids (SS), dissolved solids (DS), total nitrogen (TN), total kjeldahl nitrogen (TKN), total

phosphorous (TP), dissolved phosphorous (DP), total recoverable cadmium (Cd), total recoverable copper (Cu), total recoverable lead (Pb), and total recoverable zinc (Zn).

A bias correction factor is applied to each constituent to reduce the bias of the prediction models (Driver and Tasker, 1990:28).

The storm-runoff load model assumes that explanatory variables such as physical and land-use characteristics and climatic characteristics can explain regional variation in annual urban storm loadings. The United States was divided into three regions based upon mean annual rainfall. Areas that have mean annual rainfall less than 20 inches were designated as region I, mean annual rainfall of 20 to less than 40 inches region II, and mean annual rainfall equal to or greater than 40 inches as region III (Driver and Tasker, 1990:12). The regional delineation was employed to decrease the variability in runoff loads caused by differences in physical, land-use, and climatic characteristics.

The most accurate estimates of storm-runoff loads for urban watersheds can be obtained using the thirty-one storm-runoff-load models developed by the USGS. The models were developed using ordinary least squares regression and the coefficients of the regression models are significant at the 5-percent level (Driver and Tasker, 1990:9). Except for dissolved solids and cadmium, there was one regression model for each storm-runoff load in the three mean annual rainfall regions (Driver and Tasker, 1990:7). The models may be used to estimate storm-runoff loadings per storm event or on an annual basis. However, a bias-correction factor must be

included in the calculation to obtain an unbiased estimate of annual mean loading (Driver and Tasker, 1990:6).

The regression model equation that applies to all models which estimate storm-runoff loading is:

$$Y = \beta_0 \times X_1^{\alpha_1} \times X_2^{\alpha_2} \dots X_n^{\alpha_n} \times BCF;$$

where

Y = load (lbs);

β_0, \dots, β_n = regression coefficients;

X_1 = total storm rainfall (inches);

X_2 = total contributing drainage area (square miles);

X_3 = impervious area (%);

X_4 = industrial land use (%);

X_5 = commercial land use (%);

X_6 = residential land use (%);

X_7 = nonurban land use (%);

X_8 = population density (people per square mile);

X_9 = duration of each storm (minutes);

X_{10} = max. 24-hour precipitation intensity that has a 2-year recurrence interval (inches);

X_{11} = mean annual rainfall (inches);

X_{12} = mean annual nitrogen load in precipitation (lbs/acre);

X_{13} = mean minimum January temperature (degrees Fahrenheit);

BCF = bias correction factor. (Driver and Tasker, 1990:8)

Ten regression models were developed to predict mean annual loads at unmonitored stations that have a drainage area in the range of 0.015 to 0.85 square mile. Models were developed to estimate mean loads for ten chemical constituents -- COD, SS, DS, TN, TKN, TP, DP, Cu, Pb, and Zn. Regression models were derived for each of the ten constituents using estimates of mean storm loadings which were derived using short-term storm data and long-term storm rainfall and duration records. All variables were significant at the 5-percent level (Driver and Tasker,

1990:28). The NRE estimates mean urban storm pollutant export by solving the following equation:

$$W = 10^{\beta_0 + \beta_1 \text{SQRT(DA)} + \beta_2 \text{IA} + \beta_3 \text{MAR} + \beta_4 \text{MJT} + \beta_5 \text{X2}} (\text{BCF})$$

where, W = mean storm load (lbs);

β_1, \dots, β_5 = regression coefficients;

DA = drainage area;

IA = impervious area;

MAR = mean annual rainfall;

MJT = mean minimum January temperature ($^{\circ}$ F);

X2 = an indicator variable of commercial and industrial land uses exceeding or not exceeding 75 percent of the drainage area;

BCF = bias correction factor. (Driver and Tasker, 1990:29)

The equation predicts the mean storm loadings (W). The mean annual load may be obtained by multiplying the mean storm load (W) by the mean number of storms per year (M). For the annual storm load regression model, a storm is a rainfall in which the total rainfall is at least 0.05 inch. Storms are separated by at least six consecutive hours of zero rainfall (Driver and Tasker, 1990:22).

Buildup/washoff. In the late 1960s, researchers demonstrated the buildup of "dust and dirt" on impervious surfaces, as well as an exponential washoff of pollutant during rainfall events. These buildup and washoff mechanisms were incorporated into several computer models such as EPA's Storm Water Management Model (SWMM) and Hydrologic Simulation Program (HSPF), and the U.S. Army Corps of Engineers' Storage, Treatment, Overflow, Runoff Model (STORM)(USEPA, 1991b:8). These dynamic models are complex and can provide analysis for almost all facets of the urban runoff process. For example, SWMM simulates runoff quantity and quality from pervious and impervious areas; sedimentation and scour; dry weather

flow and pollutant routing in sewers; and receiving water quality, storage and treatment (Decoursey, 1985:411). The capabilities include the analysis of flows and pollutants through the watershed, continuous simulation, and the production of hydrographs and pollutographs at many locations along the route. The calculation of a complete probability distribution for the output allows "what-if" storm event scenarios to determine the relative effectiveness of NPS control strategies (USEPA, 1992c:5-17). To fully exploit the capabilities of these computer models requires a tremendous amount of data, but most can also be run with minimal data. Of course, the reliability of the simulation decreases as the amount of assumptions increases.

Each of the five methods discussed above (unit loads, spreadsheet, statistical method, regression, and buildup/washoff) can be used to compute the annual pollutant loading on a per-outfall basis. This capability, as previously discussed, might assist in the identification of outfalls with similar effluent characteristics. The method used is dependent on the level of analysis required. If a study objective is to provide input loads to a receiving water quality model, local site specific data will probably be required. On the other hand, the methods and models discussed are able to compare the relative contributions from different NPS pollution source areas in the absence of site specific sampling data (USEPA, 1991b:30).

Storm Water Quality Monitoring. Sampling storm water discharges can provide valuable information on the types and amounts of pollutants present in runoff. It is important to ensure that sampling data are as representative of the actual water quality conditions as possible. A representative sample can provide information

which can be used to identify pollutant sources and aid in the development of storm water pollution prevention plans. Best management practices can also be developed to control the pollution sources identified.

In storm water quality monitoring it is not possible to analyze the entire runoff from a drainage basin. The objective of water quality sampling is to collect a small portion of the storm water runoff which adequately represents the whole. If a pollutant of interest were uniformly distributed throughout the flow (a condition referred to as "well mixed"), then obtaining a representative sample would be a relatively simple matter. In reality, such uniform distribution is unusual (Childress and others, 1987:B12).

The method selected for sampling should consider the physical conditions of the drainage conveyance in order to achieve a representative sample. For example, water-quality conditions at any instant may vary with distance from the stream bank and with depth (Childress and others, 1987:B12). Water-quality is directly affected by the degree of mixing within the drainage conveyance. In turn, the degree of mixing at any cross-section of the conveyance depends on many factors. These factors include: streamflow characteristics such as velocity and turbulence; stream-channel characteristics such as width, depth, slope, and roughness; and characteristics of the contaminant or pollutant such as whether or not it is suspended in solution or attached to particles. If the runoff is highly turbulent, the flow may be subjected to rapid vertical mixing. The runoff also experiences lateral cross-stream mixing. Lateral mixing usually occurs more slowly than vertical mixing unless the width of

the conveyance is small relative to its depth (Childress and others, 1987:B12). All of these physical parameters must be considered when collecting storm water samples.

Obtaining a representative sample can be difficult considering the numerous factors affecting water-quality. In 1984, the U.S. Geological Survey conducted a surface water study in Colorado and Ohio to determine the natural existing water-quality conditions. Of the 161,000 surface-water analyses and measurements in Colorado, only 16% were judged by the samplers themselves to be representative of the cross-section sampled. Sixty-seven percent of the 75,800 surface-water analyses and measurements in Ohio were judged to be representative of the cross-section. There are two possible reasons why so few analyses were considered to be representative. One reason is related to the lack of emphasis on the need to obtain a representative sample, as compared with the emphasis placed on laboratory precision and accuracy. Another possible reason is the lack of sufficient training of field personnel (Childress and others, 1987:B14).

The EPA has established federal guidelines for the collection of storm water samples in 40 CFR 122.21 (g)(7) and 40 CFR Part 136 to aid in achieving proper sample collection and successful pollutant identification (USEPA, 1992a:36). Data required by the EPA to characterize a storm event includes: rainfall duration and amount, the length of dry weather interval prior to the storm event, the method of flow measurement, and grab and composite samples of the runoff (ISCO, 1992:6).

The regulation specifies certain criteria that a storm event must meet in order to be deemed acceptable for sampling purposes. The storm event must produce

greater than 0.1 inch of rain and must have been preceded by at least 72 hours of dry conditions (U.S. Congress, 1990:48018). In addition, the duration and total rainfall for the storm event should not vary by more than 50 percent from the average or median storm event depth and duration in the sampled area (USEPA, 1992a:15). This is the EPA's definition of a representative storm. These criteria were established to ensure that adequate storm flow would be discharged and that the storm would be typical for the area in terms of intensity and duration (USEPA, 1992a:18).

Determining Flow Rate. There are several methods which can be used to determine the flow rate of a sampled stream or conveyance. Direct measurements of flow rates are achieved using man-made flow control structures such as weirs or flumes. There are also several methods which can be used to estimate flow rates. These methods are not as accurate as the direct methods. The most common estimation methods are the bucket method, the float method, and the runoff coefficient method. All these methods are discussed below.

Weirs and Flumes. When weirs or flumes are inserted into an open channel, they create a geometric relationship between the depth of flow and the rate of the flow. A weir is a crest placed across the width of an open channel. This crest impedes the flow of water causing it to overflow the crest. Weirs can provide an accurate measurement of flow by relating the upstream head (depth of water) and the geometry of the weir. Flumes are structures which force water through a narrow channel. They consist of a converging section, a throat, and a diverging section. Flow rates can be determined by measuring the depth of flow in the converging

section and applying the appropriate formula, which is dependent upon the geometry of the flume (USEPA, 1992a:43).

Bucket Method. The bucket method of estimating flow rates is a simple estimation method. This method can only be used when the flow or discharge to be measured originates from a small, free-flowing pipe or ditch. In other words, the pipe or ditch must be elevated in such a manner that enables the flow to be captured by a bucket or other suitable container without overflowing (USEPA, 1992a:53). The bucket method consists of measuring the amount of time it takes for the bucket to be filled and the volume of discharge collected.

Float Method. The float method of estimating flow rate can be used for any discharge where the flow is exposed and is easily accessible, such as an open channel or ditch. With this method, the flow rate is obtained by estimating the velocity of the flow and the cross-sectional area of the conveyance and applying the following equation: $\text{flow rate (cfm)} = \text{velocity (ft/min)} \times \text{area (ft}^2\text{)}$. The velocity can be obtained by measuring the amount of time required for a floating object, placed in the discharge, to traverse a predetermined distance. The cross-sectional area of the discharge or conveyance can be obtained by measuring the depth of flow and the width of flow, and obtaining the product of these two values. This assumes the conveyance has a uniform, geometric cross-sectional shape and that the surface velocity is the average velocity across the entire cross section.

Runoff Coefficient Method. The runoff coefficient method is the least accurate of all the flow rate estimation methods (USEPA, 1992a:56). Runoff

coefficients represent the ratio of the peak runoff rate to the average rainfall rate for a period known as the time of concentration (Viessman and Hammer, 1985:195). In other words, runoff coefficients represent the fraction of total rainfall that will actually be transported across the ground surface as runoff. For example, paved surfaces and other impervious structures such as roofs have a runoff-coefficient of 0.70 to 0.95 which indicates that 70 to 95 percent of the rainfall will leave the area as runoff (Viessman and Hammer, 1985:197).

In order to estimate a flow rate using runoff coefficients, it is necessary to obtain the storm event's rainfall accumulation and the area of the drainage basin of interest. The estimated flow rate can then be obtained by the following formula:
Average Runoff Rate = (Ad) X (C) X (i); where Ad = area of drainage basin (acres); C = runoff coefficient, and i = rainfall depth / rainfall duration (in/hr).
When using this formula it is important to note that appropriate unit conversions should be applied to achieve the proper discharge volume.

Types of Samples As stated previously, the main objective of a sampling effort is to obtain samples which are representative and valid for the most common conditions at the sampled site. In order to achieve this goal, the EPA requires that two sets of samples be collected during a storm event, a grab sample of the runoff during the first 30 minutes of the event and a composite sample of the runoff over the next three hours (USEPA, 1992a:24).

Grab Sample Collection. A grab sample is defined as an individual discrete sample, usually one liter in volume, collected over a period of time not

exceeding 15 minutes (USEPA, 1992a:37). The grab samples which must be taken 30 minutes after a storm event begins will generally contain higher concentrations of pollutants due to what is called the "first flush effect". The first flush effect refers to the accumulation of pollutants on an impervious surface being swept away by storm water (USEPA, 1992a:25).

Composite Sample Collection. A composite sample is defined as a sample formed by mixing individual samples taken at periodic points in time or is formed by combining a continuous proportion of the flow (USEPA, 1992a:19). Composite samples characterize the average quality of the entire storm water discharge over a longer period of time.

Quality Assurance/Quality Control. Variability in analytical results, caused by errors in sample collection or analysis is unavoidable. Errors can be introduced into sample results through: selection of a sampling location or method that produces a sample that fails to represent the conditions of interest; improper use of instruments; contamination of the sample; and inappropriate methods of analysis. A quality assurance program should evaluate all aspects of sample collection, analysis, and reporting. Specific quality-assurance practices for monitoring effluents and surface and ground water affected by effluents are documented by the EPA (Childress and others, 1987:B7).

A quality control program is an essential component of quality assurance. To ensure the correctness of the samples collected, quality control encompasses routine and specific procedures that determine the quality of an individual measurement

activity. A good quality control program consists of internal and external control procedures (American Public Health Association, American Waterworks, and Water Pollution Control Federation, 1981:24). Internal controls help ensure that personnel are collecting, preserving, and handling samples with methods that have been found acceptable. Storm water samples must be handled and preserved in accordance with 40 CFR Part 136. This section describes acceptable analytical methods, including requirements regarding sample holding times, containers, sizes, and preservation requirements. Other examples of internal quality control include proper sample documentation, including sampling identification and labeling, instrument calibration, proper sample packaging, and documented chain-of-custody procedures (USEPA, 1992a:81-82). Confirming the ability of a laboratory to produce acceptable results by requiring analysis of blank, replicate, and spiked samples is an example of an external quality control method (APHA, 1981:24).

Permit System Problems

In October 1990, the U. S. General Accounting Office reported, "the current standards are generally oriented towards point sources of water pollution and often do not adequately measure nonpoint source impacts" (U.S. GAO, 1990:26). The report concludes that the inconsistencies between point and nonpoint pollution measurement are hampering efforts by the NPDES permit authorities and state NPS programs to fully develop their NPS programs (U.S. GAO, 1990:46).

Nonpoint source pollution problems and control technologies are different than those associated with point source treatment facilities. Criteria established for point source discharge control are usually not applicable to urban runoff. The standards for point sources are based on the effects of pollutants on a receiving body during periods of low-flow. Nonpoint source pollution occurs during peak flow periods and results in unique chemical and biological situations, which may have a different long-term impact than a point source discharge (Griffin and others, 1991:63). An example is the transport of sediment via storm water runoff. Point source permits dictate the total amount of solids (sediment) that can be discharged from a facility. The permit does not account for variability. Current point source NPDES standards do not account for sudden changes in background pollution levels due to natural occurrences. As such, a regulator cannot guarantee that unusual storm events will not result in a permit violation (U.S. GAO, 1990:26).

These differences may require two control standards for the same pollutant: one for point sources and one for nonpoint sources. The NPDES program will have to quantify the different impacts of all NPS pollutants if the long-term goal of water quality improvement is to be achieved (Griffin and others, 1991:63).

A few states are attempting to more appropriately measure NPS pollution by incorporating biocriteria. Arkansas, Maine, North Carolina, and Wisconsin already incorporate some form of biocriteria in their NPS pollution control program. Biocriteria simply refers to incorporating biological criteria into the NPS monitoring process. Instead of regulating NPS discharges based on numerical standards

developed for continuous point sources of pollution, NPS discharge standards are designed using criteria based on water body use. The goal is to supplement analytical chemical data with other ecological criteria that include biological and habitat considerations. The use of biocriteria goes beyond the guidelines currently provided by the EPA which promotes subjective criteria to conduct assessments based on long standing point source discharge limits (Griffin and others, 1991:63-64).

Conclusion

Nonpoint source pollution has been identified as a major cause of water quality degradation throughout the United States. All 50 states have mandated programs to address NPS pollution. The progress toward improved water quality, however, has been slow due to the magnitude and complexity of the problem.

Urban storm water runoff is a significant contributor to the nation's nonpoint source pollution problem. Impervious surfaces in an urban area lead to two distinct characteristics of urban NPS pollution: the accumulation of pollutants in high concentrations and an efficient terrain that transports a large volume of storm water discharge. Unfortunately, these unique characteristics hamper efforts to control nonpoint source pollution.

The sources of urban NPS pollution are numerous and can be related to acid rain, wind, litter, street dirt, traffic emissions, and erosion. The adverse impact of urban nonpoint source pollution on receiving waters is usually the result of high flow rates, organic pollutants, toxic heavy metals, sediment, and pathogens.

Current legislation has created a NPDES permitting program in an attempt to control and reduce NPS pollution discharges. The NPDES permits issued by the EPA will require three major areas of compliance: a NPS pollution management program; identification of storm water outfalls; and the performance of periodic sampling to demonstrate permit compliance. The development of a manageable, cost-effective NPS monitoring program is essential for the control of water pollution. The development of such a program will assist agencies, such as the U.S. Air Force, in their efforts to comply with NPDES permit requirements.

Once storm water permits are issued to individual AF bases, storm water outfalls must be monitored and sampled as specified by the permit. The EPA has established a procedure by which similar effluents can be identified and grouped together for sampling purposes. Instead of sampling each individual outfall, similar effluents may be grouped and a representative sample obtained from one. EPA's procedure outlines three options by which the combining of outfalls may be petitioned: 1) submission of a narrative description and site map; 2) submission of matrices; or 3) submission of model matrices. The use of mathematical modeling, which simulates runoff pollutant loading, can also be used as supplemental information to support the combining of similar outfalls. This effort, if successful, could substantially reduce a base's sampling burden and cost.

The NPDES permit system is not without its problems. Currently state water quality standards are formulated to detect and regulate point sources. Criteria established for point source discharge control are usually not applicable to urban

runoff. Urban runoff has peak flow rates that result in unique chemical and biological situations which have a different impact than low flow rate point source discharges. Some states are attempting to solve the problem by using a water quality analysis which incorporates biocriteria. Biological and habitat considerations may prove to be a more appropriate method of analysis.

Nonpoint sources, in contrast to point sources, are diffuse and therefore more difficult to control. As a result, the control of nonpoint sources must be approached in a different manner than that of point sources. Current standards used to control point source pollution may not effectively predict the long-term impacts that NPS pollution has on a receiving body of water.

III. Methodology

This chapter presents the methodology used to meet the objectives of this research and answer the investigative questions outlined in Chapter I. These investigative questions examined how to conduct effective storm water sampling in compliance with NPDES permit guidelines. They were:

1. What are the applicable federal and state rules and regulations governing storm water runoff at USAF installations?
2. What are the current sampling practices being used by AF NPDES Part 2 group applicants and other group applicant civilian and military programs?
3. Which sampling alternatives can be implemented to effectively ensure NPDES permit compliance?
4. What strategies and management practices can be implemented to reduce long-term sampling costs?
5. What methodology can be used by base-level environmental managers to establish a cost-effective sampling program that meets EPA guidelines?

Research Overview

This research will be a descriptive study with data gathered and analyzed to answer the above five questions. Primary and secondary data will be gathered from observational studies including: review of applicable literature; review of existing storm water sampling techniques; collection of sampling data from the USAF group applicant bases; and telephone interviews with regional and state EPA regulators. The data will be pooled from two sample groups; AF NPDES Part 2 group applicants and regional and state EPA regulators.

Air Force Coordination

The office of primary responsibility (OPR) for Air Force Clean Water Act compliance, HQ USAF/CEVC, identified the Air Force Center for Environmental Excellence, Dallas Regional Compliance Office (AFCEE/CCR-D) and Armstrong Laboratory, Occupational and Environmental Health Directorate (AL/OEBE) as the Air Force OPRs for nonpoint source pollution permit applications and compliance.

AFCEE/CCR-D was identified as the office responsible for coordinating the NPDES group permit application for the Air Force. AFCEE/CCR-D's responsibilities have included preparation and submittal of Part 1 and Part 2 of the Air Force's group application to HQ EPA. Part 1 included a characterization of 133 AF installations by industrial activity. The purpose of the submittal was to establish a baseline of potential contributors to nonpoint source pollution within the Air Force. The EPA requires a group applicant to sample 10 percent of the installations participating in a group application. The Air Force coordinated with EPA and gained approval for 15 installations to be sampled for the Part 2 submittal.

AL/OEBE was identified as the office responsible for coordinating the actual collection of the storm water sampling data for the Part 2 submittal. Armstrong Labs is the technical advisor for all base-level Bioenvironmental Engineering (BEE) offices. The BEE's at each of the fifteen bases were tasked with collecting the storm event samples. AL/OEBE is also responsible for establishing storm water sampling guidance for the Air Force.

Throughout the data gathering process, AFCEE/CCR-D and AL/OEBE provided a formal coordination channel with the EPA to ensure data objectives and data analysis remained in compliance with regulatory guidelines. They also provided site and sampling data from the 15 bases that participated in the AF NPDES group storm water application.

Data Collection Procedures

AFCEE/CCR-D and the EPA's NPDES Storm Water Hotline service were used to obtain points of contact for the state and federal EPA region permit authorities. A permit authority is the office that issues the final NPDES permit to an applicant and establishes sampling frequency and protocols. Sampling requirements were solicited by contacting state and regional POCs telephonically. The objective was to collect sampling requirements directly from the authority that would issue the NPDES permit to an installation. It was necessary to contact regional EPA offices because not all 50 states have obtained permit authority from HQ EPA. Data collection was limited to only those regional or state programs with jurisdictions that contained USAF installations. A literature review was performed to obtain applicable federal guidelines. Current sampling techniques were obtained for the AF NPDES Part 2 group applicants, using telephone and written requests.

The EPA's NPDES Storm Water Sampling Guidance Document served as the basis for identifying methods to reduce long-term sampling costs. Chapter Five of the EPA's guide suggests three methods for the identification of similar storm water

outfalls: narrative, matrix, and modeling. By identifying outfalls with similar characteristics, an installation can reduce sampling requirements and thus reduce costs.

Data Analysis Procedures

The first research question was answered using information obtained from the permit authorities and federal regulations. The data was summarized and sorted by permit jurisdiction. Information sorted by permit issuing authority was also used to guide the analysis of the third research question. The data served to ensure that sampling techniques and parameters identified met standard regulatory requirements.

To answer the second research question, the sampling strategies and techniques obtained from the group permit application programs were compiled into five categories: standard sampling procedures used, personnel management, compliance with the NPDES storm water sampling protocol requirements, equipment requirements, and suggested improvements. The categories were established to serve a two-fold purpose: to identify common sampling techniques, and to identify innovative ideas for increased sampling efficiency.

The third research question was answered using a review of applicable literature and the sampling technique data. A set of parameters were established to compare the advantages and disadvantages of the sampling techniques identified by the second research question. The categories developed to compare the different programs were: in-house, automatic sampler and contractor.

The methods identified during the literature review as acceptable to justify a reduction in sampling were used to answer the fourth research question. A case study was performed using data obtained from one of the group applicant bases. The case study was designed to demonstrate the applicability and validity of a technique to petition a permit authority to reduce total sampling requirements.

Summary

The final step in this study, question five, was to generalize the findings and provide recommendations for development of a cost-effective storm water sampling program. The findings in Chapter V and VI were presented to AFCEE/CCR-D and AL/OEBE. The sampling recommendations have also been provided to Armstrong Laboratory, Brooks AFB, Texas, for use in the storm water section of the Air Force Bioenvironmental Engineering sampling guide.

IV. Results of AF Storm Water Sampling Survey

As stated in Chapter I, the purpose of this research was to develop a storm water sampling guide that will allow Air Force installations to conduct cost effective storm water sampling in accordance with NPDES permit guidelines. This chapter examines the data collected with respect to the first two investigative questions of Chapter I.

Overview

The chapter begins with a description of the regulatory requirements related to storm water sampling. A telephone interview of all NPDES permitting authorities and a literature search was conducted in order to clearly identify all applicable requirements. Data obtained from the telephone interview and literature search are discussed. The chapter continues with an analysis of sampling techniques employed by the AF Part 2 group permit applicants. The sampling techniques were identified through the use of a telephone interview with each permit applicant. Results of the telephone survey are presented for each interview question.

The chapter concludes with a discussion of civilian storm water sampling programs. An attempt was made to identify a model civilian sampling program to examine civilian sampling practices and compare their sampling techniques with those of the AF Part 2 group applicants.

Storm Water Sampling Regulatory Requirements

In order to identify all applicable federal and state rules and regulations governing storm water runoff at USAF installations, a telephone survey of the thirty-one storm water NPDES permit authorities was conducted from 3-15 June 1993. The EPA's Storm Water Hotline (703-821-4823) and the NPDES Storm Water Sampling Guidance Document served as a primary source for obtaining points of contact for each permit authority (USEPA, 1992a:12-15). The overall response rate to this survey was 100 percent. All respondents indicated that the sampling protocol outlined in the EPA Storm Water Sampling Guidance Document was currently the only source of sampling requirements used in their jurisdiction. The State of Wisconsin did report that they were in the process of developing a supplement to the EPA's document.

The sampling requirements established by the EPA and used by the permit authorities can be divided into two categories: standard procedures and storm water specific permit procedures. All storm water discharges must be sampled and analyzed in accordance with the standard test procedures provided in 40 CFR Part 136. These procedures are not storm water specific, they are standard data collection procedures.

Within the EPA's NPDES Storm Water Sampling Guidance Document, there are sampling protocols presented that are specific to storm water discharges. They are designed to provide information on the types and amounts of pollutants present in storm water discharges. The storm water specific sampling protocols focus on three main areas: sampling a representative storm event, the parameters that must be

analyzed, and the type of sample collection required for each constituent. These components are discussed below.

Representative Storm Event. Storm water discharge permit application requirements establish specific criteria for the type of storm event that is considered representative:

1. The depth of the storm must be greater than 0.1 inch accumulation;
2. The storm must be preceded by at least 72 hours of dry weather;
3. Where feasible, the depth of rain and duration of the event should not vary by more than 50 percent from the average depth and duration. (USEPA, 1992a:15)

Determining whether a storm is representative, is a two step process. First, data on local weather patterns should be collected and analyzed to determine the range of representative storms for a particular area. Second, these results should be compared to measurements of duration, intensity, and depth of the sampled storm to ensure that the sampled storm fits the representativeness criteria. Industrial group applications must include sampling data from at least one representative storm event.

Parameters to Be Analyzed. EPA guidance stipulates that industrial facilities submitting a group application must provide sampling data on the following parameters, as required in 40 CFR 122.26(c)(1)(i)(E):

1. Oils and grease (O&G), hydrogen ion concentrations (pH), 5-day biochemical oxygen demand (BOD₅), chemical oxygen demand (COD), total suspended solids (TSS), total phosphorus, total kjeldahl nitrogen (TKN), and nitrate plus nitrite, nitrogen;
2. Any pollutant listed in the facility's NPDES permit for its process wastewater (if the facility has an existing NPDES permit) or any pollutant

limited in a NPDES permit applicable to the sampling facilities within the group permit;

3. Any pollutant known or believed to be present based on significant materials and industrial activities present onsite [as required in 40 CFR 122.21(g)(7)];

4. Biological toxicity testing data if the facility's NPDES permit for its process wastewater lists biological toxicity;

5. Flow measurements or estimates of the flow rate, the total amount of discharge for the storm events sampled, and the method of flow measurement or estimation;

6. The date and duration of the storm events sampled, rainfall measurements or estimates of the storm event which generated the sampled runoff, and the time between the storm event sampled and the end of the previous measurable (greater than 0.1 inch rainfall) storm event. (USEPA, 1992a:97)

Type of Sample Collected. Industrial applicants must collect two types of storm water samples: 1) grab samples during the first 30 minutes of discharge; and 2) flow-weighted composite samples collected during the first 3 hours of discharge (or the entire discharge if it is less than 3 hours). 40 CFR 122.21(g)(7) requires a grab sample to be obtained to provide data for pH, temperature, cyanide, total phenols, residual chlorine, oil and grease, fecal coliform, and fecal streptococcus. Sample data may be collected either manually or using an automatic sampling device, with the exception of oils and grease (O&G) and volatile organic compounds (VOCs) which the EPA requires to be collected manually. O&G must be collected manually because some automatic samplers use plastic parts which oils and grease tend to stick to instead of being deposited into the sampling bottle. VOCs must be collected manually due to their volatile nature which requires the sample bottles to be closed immediately

after the sample is obtained. Regardless of what type of sample is taken, time-dependent parameters such as pH and temperature must be determined during sample collection.

USAF Storm Water Sampling Survey Analysis

A survey was conducted via telephone interview with the 15 Air Force installations selected by Armstrong Laboratory, AL/OEBE, and the EPA as representative for the AF group application. The overall response rate of this survey was 100 percent. However, three of the respondents (3 of 15) indicated that they were no longer required to participate in the application process and one respondent had been unable to perform sampling because of the lack of a representative storm event. Thus, of the total sample surveyed, 11 of 15 provided data and information regarding their storm water sampling operations. All respondents, with the exception of one, used personnel from the Bioenvironmental Engineering office to conduct the sampling effort. One respondent used a private contractor to collect samples and the contractor's responses to the interview have been included in the survey results.

The five major areas of interest discussed during the Air Force survey were: standard sampling procedures used, personnel management, compliance with the NPDES storm water sampling protocol requirements, equipment requirements, and suggested improvements.

The standard sampling procedures category is comprised of questions relating to techniques which are common to most sampling protocols. For example, the

techniques used to collect a grab sample are common to treatment plant, stream, and storm water runoff. The intent was to determine if standard sampling procedures and techniques, when employed under the unique conditions stipulated by the permit application rules (e.g. during a storm event), resulted in problems in sample collection. Questions in the personnel management category were used to determine how personnel were managed before and during a storm event. The questions were designed to determine how each base attempted to ensure timely and sufficient data collection for each outfall sampled. A question was included in this category, to determine if current training adequately prepares personnel to perform storm water sampling.

The third category of questions was designed to determine problems or successes each base experienced trying to comply with the storm water sampling protocol developed by the EPA. The questions specifically addressed procedures outlined in the July 1992 EPA document NPDES Storm Water Sampling Guidance Document. These procedures differ from the standard sampling procedures in that they were designed by the EPA to address data requirements necessary to specifically quantify storm water runoff characteristics.

The final category, suggested improvements, is a summary of suggestions and comments each base provided. This category was provided to allow each base to suggest ways the sampling task could be improved or done differently to improve the overall sampling task. Each base was also asked to provide information related to problems they experienced which were not addressed during the interview.

Standard Sampling Procedures Used. This section of the survey, questions one through five, collected data on the use of standard sampling procedures as they relate to the collection of storm water samples. Responses from questions one through five are summarized in Table 5.

Question #1. Did you have a problem collecting grab samples?

Two of the respondents indicated difficulty collecting grab samples. Both indicated complications due to a lack of runoff flow at each outfall to be sampled. One base was unable to collect a grab sample at an outfall because the outfall never received any runoff flow. Another problem that hampered collection was limited outfall access due to dense vegetation.

Question #2. Did you have a problem collecting composite samples?

Three of the respondents indicated difficulty collecting composite samples. One installation attempted to use an automatic sampler to collect the composite samples. The sampler had problems with the distributing arm and only filled the sample bottles half-full. Another base was unable to collect composite samples for the specified time (3 hours) because snow pack in the drainage basin absorbed the runoff. A third base was unable to measure flow rate, therefore, a flow-weighted composite could not be collected.

Question #3. Did you have a problem compositing the sample?

One respondent indicated difficulty compositing VOCs, cyanide, and chromium VI samples due to insufficient manpower. Two bases were unable to collect composite samples because an outfall did not receive three hours of continuous

runoff. All respondents indicated that they composited their samples in the laboratory not in the field.

Question #4. Did you experience Quality Assurance/Quality Control problems with the laboratory analyzing your samples?

Four of the respondents indicated that no QA/QC procedures were used to verify the integrity of samples during transport or laboratory analysis. Only one base reported submitting field blanks to the lab for analysis as a quality assurance measure.

Question #5. Did you experience problems meeting time limitations such as the constraint on sample holding time, or the time limits between sample collection and delivering it to the laboratory?

Three respondents indicated that they had difficulty meeting the holding time limitations. One problem identified was that if a representative storm event occurred during a weekend or holiday, no laboratories were available to perform analyses. A second problem was a lack of coordination prior to the storm event between the sampling crew and the laboratory. The associated delay at the lab resulted in samples exceeding holding time limits. The final problem identified was one concerning sample submittal restrictions. At one laboratory, coliform and BOD samples were accepted only on certain days of the week.

Table 5

USAF Storm Water Sampling: Standard Procedures

AF Base	Problems w/ Grab Sample Collection	Problems w/ Composite Sample Collection	Problems w/ Sample Compositing	QA/QC Procedures Used	Problems w/ Sample Analysis Time Constraints
Base 1	No	No	No	No	No
Base 2	No	No	No	Yes	No
Base 3	No	No	No	--	No
Base 4	No	No	Yes	No	No
Base 5	No	No	No	No	No
Base 6	No	Yes	N/A	Yes	Yes
Base 7	Yes	No	No	Yes	No
Base 8	No	Yes	No	Yes	Yes
Base 9	Yes	Yes	N/A	Yes	No
Base 10	No	No	No	No	No
Base 11	No	No	No	Yes	Yes

Personnel Management. Questions six through nine were designed to collect data concerning personnel training, manpower requirements, and organization of personnel in the collection of storm water samples. The intent was to determine the

level of effort required by personnel to meet the sampling requirements. With the exception of the one contracted sampling effort, personnel from the base Bioenvironmental office were tasked to collect all storm water samples. Two of the respondents recruited additional personnel from base Civil Engineering. Responses to questions six through nine are summarized in Table 6.

Question #6. What type of formal training on storm water sampling did the sampling team have?

Personnel training on the sampling of storm water was found to be limited. Three of the respondents indicated that they had never received formal training of any kind. Five respondents reported receiving a block of instruction from the AF Bioenvironmental Engineering course (course number 93-0408/B3ABY90730-000) taught at the USAF School of Aerospace Medicine, Brooks AFB, TX. This training included the actual collection of wastewater samples and a discussion of storm water sample collection. The student was required to distinguish between grab, composite, and integrated samples and their appropriate uses. The measurements of flow rates using flow meters, weirs, and flumes were discussed. The student was required to determine the volume of discrete samples required to prepare a flow-proportional composite sample. The training also included water pollution analyses which introduced procedures for biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), and total kjeldahl nitrogen (TKN).

Question #7. Please indicate how many personnel were required to perform the sampling and approximately how much time was required to perform the sampling?

Manpower requirements per sampled outfall varied greatly. Six respondents reported that one person per outfall was sufficient to perform sampling. Four respondents used two people per outfall. and one base used three people per outfall. Total time required to complete the sampling tasks ranged from 6 to 12 hours.

Question #8. Did you have a problem with manpower shortages?

The level of manpower per base required to perform the sampling was generally found to be dependent on the number of outfalls to be sampled. The number of outfalls sampled per base and the required personnel can be found in Table 6. The number of outfalls sampled per base ranged from one to seven. Seven respondents reported no shortage of manpower. Three bases reported manpower shortages due to other conflicting priorities. One base did not have enough personnel to sample all of its outfalls simultaneously due to the large number of outfalls to be sampled.

Question #9. How and when were field sampling crews notified of an impending storm event?

Coordination of the sampling crew prior to a sampling event was accomplished primarily through the telephone recall roster. Ten bases used the recall roster to notify sampling crew members of an impending sampling task. The base weather squadron was used by six of the respondents to determine the likelihood of a storm

event. If the likelihood was high the sampling crew was notified and reported for sampling duty.

Table 6

USAF Storm Water Sampling: Personnel Management

AF Base	Number of Outfalls Sampled	Personnel Required per Outfall	Manpower Shortage	Received Training	Crew Notification Method
Base 1	3	3	No	Yes	Telephone Recall
Base 2	2	2	Yes	Yes	Telephone Recall
Base 3	4	1	No	No	Telephone Recall
Base 4	7	1	Yes	Yes	Telephone Recall
Base 5	3	1	No	Yes	Assembled next morning
Base 6	5	1	Yes	No	Telephone Recall
Base 7	7	2	No	Yes	Telephone Recall
Base 8	1	1	No	Yes	Telephone Recall
Base 9	1	2	Yes	No	Telephone Recall
Base 10	2	1	No	Yes	Telephone Recall
Base 11	2	2	No	Yes	Telephone Recall

NPDES Storm Water Sampling Guidance Protocol Compliance. This category of questions was designed to determine problems or successes each base experienced trying to meet the EPA's storm water sampling protocol. Responses to questions 10 through 16 are summarized in Table 7.

Question #10. Did you have a problem determining whether a sampled storm event was a representative storm?

Seven of the respondents indicated problems either (a) defining a representative storm for their area or (b) determining before, during, or after a storm if the event that had been sampled was actually a representative storm. One base sampled for three hours only to find that the event was not representative. Two bases had difficulty experiencing a representative storm. One base was in a six year drought, the other was having one of the wettest years in history. One base had difficulty meeting the 72 hour dry period because it received daily rain events for a prolonged period of time. A final problem was an inability to define a representative storm event based on data from the base weather station. The base weather station summarizes their storm data on a daily basis instead of on a per storm event basis. Therefore, a representative storm event proved difficult to determine.

Question #11. Did you have a problem determining when to sample? How was the start time of the storm event determined?

All respondents expressed difficulty predicting exactly when it was going to rain. In short they, had a hard time trying to second guess mother nature. A combination of local weather forecasts and physical observations were used to verify

the actual onset of a rain event. Eight bases indicated no problem establishing the start time of the storm event, basing their decision to start sampling on an increase in the flow rate at the outfall. Two bases indicated no problem establishing the event start time, basing their decision on the time the weather service indicated that the storm event officially started.

Question #12. Did you have a problem determining what to sample (BOD5, COD, total kjeldahl nitrogen, etc.)?

None of the respondents indicated difficulty in this area. A contractor identified the pollutants of concern at each of the group application bases and all applicants assumed this to be an adequate determination of what to sample. It is important to note that the respondents assumed the contractor was successful in identifying all pollutants of concern. The survey identified all pollutants which required collection by outfall.

Question #13. Did you have a problem determining where to sample (outfall location)?

None of the respondents indicated difficulty in this area. The same contract used to identify pollutants of concern, also identified the location of all outfalls where sample collection was required. All of the applicants assumed this determination to be adequate. Here again, it is important to note that the applicants assumed the contractor was correct in determining sample locations.

Question #14. Did you have a problem determining the flowrate of the sampled channel, stream, or other water conveyance?

Four respondents indicated problems determining flow rate. Two of the four used the float method, one used the bucket method, and one made no attempt to determine flowrate. Problems determining the flow rate were attributed to the following factors: clogged culverts, not having a flow meter at time of sampling, and having to estimate flow rates because a more accurate method was not available.

Question #15. How did you determine the flowrate?

A variety of methods were used to determine flow rate. Two bases used the runoff coefficient method. Three bases used the float method. One base used the bucket method. One base used an automatic sampler to determine flowrate. One base did not measure flowrate. Three bases used hydrologic models to determine flow rates for various channel depths. This information was then summarized in a table using flowrate versus channel depth. This allowed for a quick determination of the channel flowrate during the storm event by measuring the channel depth and cross referencing the table to find the predetermined flow rate for the conveyance.

Question #16. Did you have problems determining if runoff in a water stream, or channel, etc was well mixed?

Three of the respondents indicated that they assumed the runoff was well mixed. One base stated that this requirement was "at the bottom of their priority list" when deciding whether or not to sample and were unsure if the outfalls sampled were well mixed.

Table 7

USAF Storm Water Sampling: EPA NPDES for Storm Water Requirements

AF Base	Problem with Representative Storm Definition	Problems Deciding When to Sample	Problems Deciding What to Sample (constituents)	Problems Determining Outfall Locations
Base 1	No	No	No	No
Base 2	Yes	No	No	No
Base 3	No	No	No	No
Base 4	Yes	No	No	No
Base 5	No	No	No	No
Base 6	Yes	No	No	No
Base 7	Yes	No	No	No
Base 8	No	Yes	No	No
Base 9	Yes	No	No	No
Base 10	Yes	No	No	No
Base 11	Yes	No	No	No

AF Base	Problems Determining Flow Rate at the Outfall	How was Flow Rate Determined	Problems Determining if runoff was Well Mixed
Base 1	No	Measured depth and referenced table	Assumed mixed
Base 2	Yes	Float method	No
Base 3	No	Measured depth and referenced table	No
Base 4	Yes	Estimated w/ float method	Assumed mixed
Base 5	No	Runoff coefficient method	No
Base 6	No	Measured depth and referenced table	Assumed mixed
Base 7	Yes	Bucket method	No
Base 8	Yes	Was not measured	No
Base 9	No	Automatic sampler	Yes
Base 10	No	Float method	No
Base 11	No	Runoff coefficient method	No

Equipment Requirements. This section of the survey, questions 17 through 20, provided the respondents with an opportunity to report special equipment requirements of the sampling effort. Responses to questions 17 through 20 are summarized in Table 8.

Question #17. If an automatic sampler was used, did you experience problems with its performance?

Two of the respondents reported using automatic samplers to aid in the collection of composite samples. One respondent reported problems with the sampler. The sampler's distribution arm which administers the sampled water to its containers, malfunctioned and deposited most of the sample outside of the container.

Question #18. Were there additional equipment requirements, over and above equipment the Bioenvironmental shop already had on hand, as a result of the storm water sampling task?

Additional equipment such as ice coolers, rain suits, rain gauges, tape measures, pH meters, hand held radios, sampling containers, graduated cylinders, and waders were required to successfully complete the sampling task. As an interesting side note, one respondent was required to supply his sampling team with a firearm for protection against possible bear attacks.

Question #19. Did you receive an adequate safety briefing concerning all hazards encountered during sampling?

All respondents reported receiving an adequate safety briefing. Lightning associated with summer storms was a primary safety concern for all respondents. All

respondents terminated sampling efforts if lightning conditions were reported or observed. Steep embankments and slippery footing can make sample collection dangerous. The sampling of outfalls during night hours presented additional safety hazards for three respondents.

Question #20. Do you feel you had the proper safety equipment?

All of the respondents, with one exception, felt they were properly equipped with safety equipment.

Table 8
USAF Storm Water Sampling: Equipment

AF Base	Automatic Sampler Used	Problems w/Automatic Sampler	Additional Equipment Required	Safety Equipment Required
Base 1	No	N/A	Yes	Rain gear, Rubber gloves
Base 2	No	N/A	Yes	None, Minimum hazards
Base 3	No	N/A	Yes	None, Minimum hazards
Base 4	No	N/A	Yes	Life preservers Portable phone
Base 5	No	N/A	No	None, Minimum hazards
Base 6	No	N/A	Yes	None, Minimum hazards
Base 7	No	N/A	Yes	None, Minimum hazards
Base 8	No	N/A	No	None, Minimum hazards
Base 9	Yes	Yes	Yes	None, Minimum hazards
Base 10	No	N/A	No	None, Minimum hazards
Base 11	Yes	No	Yes	Rubber Gloves

Additional Survey Information. This section of the survey, questions 21 and 22, provided respondents an opportunity to identify additional problems they had encountered and to suggest improvements. Responses to questions 21 and 22 are summarized in Table 9.

Question #21. Overall, what problems did you encounter throughout the sampling process that were not mentioned above?

The predominant problem identified was a lack of personnel training for the sampling of storm water. This lack of training, coupled with vague EPA sampling guidance, created a problem for all respondents. Other problems identified were related to unpredictable weather. Threatening rain storms which did not materialize caused false starts and repeated trips to the monitoring sites resulting in a waste of time and money. In the more arid parts of the country, the lack of storm events became a problem. In the northern part of the country snowmelt created a problem by absorbing runoff from storm events.

Question #22. What do you think could be improved or done differently to improve the overall sampling task? What improvements do you think could be made?

The suggestions received in response to this question were mainly focused around manpower and the requirements of the EPA's sampling protocol. It was suggested that more base specific sampling guidance be developed. The need for a better flowrate determination method was also recognized to improve the sampling process. Other respondents suggested that the representative storm event criteria is

too restrictive and should be reevaluated. One respondent suggested that automatic samplers be used to meet the sampling requirement. Almost all the respondents indicated that the sampling task was too manpower intensive and felt that either the Bioenvironmental manpower should be increased or a contract should be let to meet the requirement.

Table 9

USAF Storm Water Sampling: Suggested Improvements

AF Base	Suggestion
Base 1	None
Base 2	Each base should develop a base specific sampling guidance
Base 3	None
Base 4	Manpower of BEE shop should be increased to meet the tasking or an outside contractor should be hired
Base 5	None
Base 6	The Representative Storm Event criteria is too restrictive and should be reevaluated.
Base 7	Improved methods should be developed to measure flowrates
Base 8	Develop a mandatory storm water sampling training program
Base 9	Develop a base specific storm water sampling plan for each base
Base 10	None
Base 11	Use automatic samplers to improve process

Civilian Storm Water Sampling Programs

An effort was made to identify civilian sampling programs, with the assistance of the interviewed NPDES permitting authorities, that are similar to the AF group and might serve as model programs. Each of the interviewees reported that they had no knowledge of an existing civilian sampling program within their jurisdiction that was similar to the one employed by the AF Part 2 group applicants. The NPDES permitting authorities also stated that it is too early in the permitting process for them to have identified a model storm water sampling program. In conclusion, the authors were unable to identify a civilian storm water sampling effort similar to the Air Force.

V. Key Elements of Storm Water Sampling

This chapter addresses investigative question number three as presented in Chapter I. Three options available to the AF for storm water sampling were identified as a result of the telephone survey discussed in Chapter IV. The advantages and disadvantages of each option are discussed and a preferred option is identified. This chapter also presents key elements of a storm water sampling program that should be considered.

Overview

There are three options available to the AF for the sampling of storm water: let sampling contracts, conduct in-house manual sampling, or conduct in-house sampling using automatic samplers. The pros and cons of each option is discussed in terms of four evaluation criteria: (1) equipment cost, (2) overall cost, (3) AF manpower requirements, and (4) results of sampling effort. A preferred option is then identified. This preference is based on data gathered in the telephone survey with each group applicant base. It is important to note the limitations that must be associated with conclusions drawn from the telephone survey. The survey consisted of a small number of respondents and any conclusions drawn from subsequent analysis of this survey should be generalized with caution.

A summary of the most successful sampling techniques employed by the group applicant bases is then provided. The objective is to present the key elements of a storm water sampling program which must be addressed in order to achieve success.

Because of differing site conditions, the variable nature of rain events, and different analytical considerations for certain pollutants, the logistical needs for sampling will be different at each Air Force installation. Therefore, specific sampling requirements will vary. With this in mind, the intent is to describe the most critical elements of storm water sampling, based on information gained during the AF questionnaire. The elements discussed are those which must be addressed when developing an in-house storm water sampling program.

Storm Water Sampling Options

The effectiveness of a storm water sampling program can be measured by comparing inputs, such as manpower and money, to the outcomes, in this case successfully meeting all regulatory requirements. The following discussion will compare the relative effectiveness of three options available to the AF for storm water sampling. This, of course, is not an exhaustive list of available options, but it represents those options identified during the survey. The options are (1) let storm water sampling contracts, (2) conduct in-house manual sampling using AF personnel, and (3) conduct in-house sampling using AF personnel with the aid of automatic sampling devices. The pros and cons of each option will be discussed in terms of their respective cost, outcome, and manpower demand. For each option, cost and manpower demand will be ranked from highest to lowest. This, as stated earlier, will be based on the information obtained from the sampling survey.

Option 1: Contract. Contracting for storm water sampling has an advantage over the other two options in that it doesn't require significant manpower from the AF Bioenvironmental Engineering (BEE) shop. (The contract would of course require the time of other AF personnel such as a contracting officer and contract management personnel). This option would be less manpower intensive on the BEE shop than the other two options. This option could also guarantee a satisfactory outcome. The contract statement of work (SOW) could be written to mandate that the sampling effort meets all applicable state and federal regulations. If the end product did not meet with regulatory approval, the contractor could be held liable and forced to repeat the sampling effort at no additional cost to the government. It is important to note, however, that this risk to the contractor would certainly be included in the initial contract cost. Thus, the disadvantage associated with this option is the contract cost. For example, one base obtained a contract to sample storm water at a cost of \$82,000. This contract required the contractor to provide sampling and analysis for one water quality survey. The contractor was also required to provide technical assistance for another. The contractor sampled during winter deicing operations. The survey included taking samples during three periods: a dry period, (after approximately 2 weeks with no significant precipitation); during a significant run-off event after period of deicing operations; and 24 hours after the significant run-off event. The survey collected a maximum of 150 samples. The samples were analyzed for: the identification of algae species, nitrogen, oxygen demand, suspended and dissolved solids, iron, pH, temperature, and dissolved oxygen content. The

contractor also determined stream flow and discharge flow, and prepared a study report which summarized the sampling results.

Option 2: In-house Manual Sampling. The greatest advantage associated with this option is its low equipment cost. The equipment required to perform this option is relatively minimal as revealed by the replies to question #18 of the phone questionnaire. The major disadvantage with this option is the level of manpower that would be required to conduct the sampling. This was found to be an average of two people per outfall according to the phone questionnaire. Another disadvantage is the cost associated with resampling. If the sampling effort does not produce a product that will meet regulatory requirements there is no recourse but to repeat the sampling effort at government expense. According to the phone survey, three of the eleven respondents had to repeat their sampling efforts due to exceeding sample holding times, erroneously sampling storms that were not representative, or malfunctioning automatic sampling equipment.

Option 3: In-house Sampling Using Automatic Samplers. Contrary to common belief, this option has no advantage over option 2 concerning manpower requirements. Ideally, with this option, one person could install the automatic sampler and then allow it to perform the entire sampling process without further intervention. This advantage is diminished, however, due to the fact that manual grab samples for Oil and Grease and VOCs are still required when using automatic samplers. The EPA will not allow the submission of Oil and Grease and VOC samples that are collected using an automatic sampler. The BEE shop, therefore, would still be required to

collect these constituents manually while employing the automatic sampler for composite sample collection. Another disadvantage with this option is the unreliable performance of the sampling device. This was demonstrated by one of the two applicants that used the automatic sampling device and experienced equipment malfunctions. The equipment cost associated with this option would be relatively high compared to the manual collection option. For example, a storm water sampling package purchased by one AF base cost \$20,700. This package included three portable samplers with accessories, three storm water monitoring programs, a data transfer unit, a data analyzer software package, three flowmeters with depth sensors, and three rain gauges. And finally, as with option 2, results are not guaranteed to meet regulatory criteria.

Table 10 summarizes the three options and the evaluation criteria. Each option is measured relative to the other two.

Table 10. Evaluation of Sampling Options

Option	Equipment Cost	Overall Cost	AF Manpower Requirement	Results of Sampling Effort
Contract	Included in Overall Cost	High	Low	Addressed by S.O.W.
In-house manual	Low to Moderate	Low	High	No guarantee
In-house automatic	High	Moderate	Moderate to High	No guarantee

Preferred Option

Based on information from the telephone survey, the in-house manual sampling option is the preferred option. This option has the lowest overall cost associated with it. The automatic sampler option is plagued by the requirement for manual collection of O&G and VOCs and poor performance. It is recommended that automatic samplers not be used until their performance record is improved. The contract option is unfavorable due to its high overall cost. This cost could become excessive since there is a continuing sampling requirement. It is important to note that the preferred option will require the further development of formal training for BEE personnel involved in the sampling of storm water. This can be accomplished by the School of Aerospace Medicine at Brooks AFB and is currently being addressed. It is also important to note that the preferred option may not be the optimum option for all AF bases. Bases with limited BEE manpower and lots of environmental compliance funds may be better off pursuing the contract option instead of in-house manual sampling.

Elements of In-house Storm Water Sampling

Key issues which should be addressed when developing an in-house storm water sampling program are: personnel, storm event definition, mobilization strategy, rain gauge information, equipment, sampling procedures, flow data, quality assurance, and safety.

Personnel. One person can successfully collect samples at a small, easily accessible outfall, like the end of a pipe in a flat area. A maximum of three people

may be required at an outfall that is located in dense vegetation with steep embankments. Remember that not all outfalls must be sampled during the same storm event, so to ease the manpower burden, decrease safety problems, and increase potential for correct sample collection it may be advisable to sample only a portion of the outfalls during any single storm event. Coordination during a storm event is especially critical at remote locations. The use of hand held radios can assist in the coordination of first flush sampling. Adequate training of personnel is essential. It is worthwhile to verify the training of personnel on how, where, and when to take and preserve a sample. Correct sample collection is critical because one doesn't know when the next representative storm event will occur.

Storm Event Definition. It is important to work with the permit authority to find out if they will be flexible with the representative storm event definition. Several group applicant bases were able to modify the restrictions on what was considered a representative storm event. This greatly increased the number of potential storms which they could sample and, thus, reduced false starts.

Mobilization Strategy. Getting to the outfalls before the first flush sample must be collected requires prior planning and coordination with the local weather squadron. Bases which successfully met the first flush time constraints established a telephone recall system that was implemented by the base BEE upon verification of an impending storm event from the weather squadron. An additional component of mobilization is to ensure that a lab is available to receive time critical samples.

Rain Gauge Information. Rainfall data must be recorded in the format required by the regulator. Do not assume that the weather squadron records rain data in the format that is required by the regulator.

Equipment. The number of sampling bottles and coolers required to preserve samples will be more than what is commonly stocked by the base BEE. A review of all parameters which require samples and the total number of grab and composite samples per outfall will determine the number of bottles and coolers required. In order to facilitate a quick response, all sampling equipment should be kept in a state of readiness. All necessary sampling bottles and paperwork should be pre-labeled and placed in an ice cooler premarked with the outfall site number (i.e. outfall 001, 002,...). This should be done for each outfall to be sampled. The refrigerated storage capacity at the BEE facility must also be considered.

Sampling Procedures. To ensure a full understanding of the magnitude and phasing of the sampling task, establish beforehand the quantity of samples which will be required at each outfall and the time required to obtain each sample. As suggested earlier, sample bottles should be numbered and labeled before leaving for the field. Ensure personnel at all outfalls understand that flow data collection is as important as storm water sample collection.

Obtaining Flow Data. Flow rate can be determined based on the geometry of a drainage conveyance. Once the conveyance geometry is determined, a table of water depth measurements and corresponding flow rates can be developed. This should be done before sampling is conducted. With this accomplished a flow

measurement can be obtained during a storm event by measuring the depth of water in the conveyance with a gauged stick and referring to the table to obtain the flow in the conveyance. This tabular information will also assist in deciding when to take the first grab sample. Personnel can base the event start time on the increased flowrate in the conveyance. This technique may be easier than the radio method previously discussed.

Quality Assurance. Do not forget QA/QC-- data collection is a time consuming and tedious task. Proper sample collection will prevent the need to do sampling again or answer a permit violation to the EPA simply because the BEE technician, lab technician, or shipper mishandled the samples.

Safety. Do not sample when there is lightning in the area or if there is a potential for flash flooding. Proper rain gear and boots are essential for all personnel. Personnel at each sampling site should be provided with communications equipment and a first aid kit. Also for safety purposes, a minimum of two people per outfall should be used for remote sampling locations.

VI. Case Study: Matrix Technique to Identify Substantially Identical Outfalls

This chapter addresses investigative question number four as presented in Chapter I. This chapter demonstrates the implementation of a matrix technique and simple mathematical modeling to identify similarly identical storm water outfalls.

Overview

The goal of this case study is to show how adequate justification can be developed to receive approval from a permit authority to reduce sampling requirements at an AF installation.

As presented in 40 CFR 122.21(g)(7),

when an industrial applicant has two or more outfalls with substantially identical effluents, the permitting authority may allow the applicant to test only one outfall and to report the quantitative data that also apply to the substantially identical outfalls.

A review of procedures established to petition the EPA for substituting identical effluents was detailed in Chapter II. The three techniques to identify similar outfalls are narrative, matrix, and matrix models. The matrix method will be used in the case study. Facilities attempting to demonstrate that storm water outfalls are substantially identical may submit matrices describing specific information associated with each outfall to the permitting authority. Petitioners must demonstrate, using matrices, that the outfalls have storm water discharges that meet the following criteria:

- 1) Substantially identical industrial activities and processes;
- 2) Substantially identical flows, as determined by the estimated runoff coefficient and approximate drainage area at each outfall;
- 3) Substantially identical storm water management practices (such as retention ponds, enclosed areas, diversion dikes, gutters, and swales) and material management practices (such as protective coverings and secondary containment); and
- 4) Substantially identical significant materials that may be exposed to storm water [including, but not limited to, raw materials, fuels, materials such as solvents, detergents, and plastic pellets; finished materials such as metallic products; raw materials used in food processing or production; hazardous substances designated under Section 101(14) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); any chemical the facility is required to report pursuant to Section 313 of Title III of the Superfund Amendments and Reauthorization Act (SARA); fertilizers; pesticides; and waste products such as ashes, slag, and sludge that have the potential to be released with storm water discharges as per 40 CFR 122.26(b)(12)]. (USEPA, 1992b:106)

This case study will demonstrate how an AF installation can address the four previous criteria in an effort to justify to a permit authority that substantially identical storm water outfalls exists.

This chapter also presents a mathematical modeling technique used to compute NPS pollutant loading at Altus AFB, Oklahoma. EPA guidelines do not require the submission of model results within a petition, but they have been included in the case study as supplemental information to assist in the justification that outfalls are similar. The case study presentation demonstrates how mathematical modeling can be used to identify similar outfalls at AF installations, thereby supporting the petition.

The case study examines data collected from Altus AFB, which is an AF group application sampling base. Altus AFB is a flight training installation. On 1

July 1993, control of the base transferred to Air Education and Training Command (AETC). The installation's primary mission is to provide transition and upgrade training for aircrew members on the C-141 Starlifter and the C-5 Galaxy aircraft. A tenant unit at Altus AFB is the 340th Air Refueling Wing which is responsible for training KC-135 Stratotanker aircrews to perform air refueling operations.

Case Study Data Collection

Data for this case study was collected from several sources including: site maps, results from a storm water analysis report performed at Altus, the AF Part 1 NPDES group storm water permit application data base, EPA guidance, engineering references and primary data calculated by the authors. The site maps used included Tab G-3, Storm Drainage System and Tab D-1, Base Comprehensive Plan Land-use Categories of the base master plan. The storm water analysis report was completed by a contractor. Armstrong Laboratory, Brooks AFB, TX let the contract to investigate Altus as a participant in the AF NPDES group permit application process. The scope of this investigation was to identify:

1. areas of industrial activity;
2. storm water outfalls draining the industrial areas;
3. substantially identical outfalls;
4. chemicals for which quantitative data will be required
5. the most cost effective method of certifying that there are no non-storm discharges into the storm water system

6. cost estimates for weir construction and for conducting initial quantitative analyses. (AL/OEBE, 1993:v)

Industrial Activities

The identification of the areas of industrial activity at an Air Force installation is central to complying with the storm water regulations, because only those storm water discharges associated with industrial activities are covered. As previously mentioned, all installation activities at Altus AFB were examined by a contractor to determine if any activities fell into one of the 11 categories of industrial activities. These eleven categories are listed in Appendix B.

A review of industrial activity is also required to meet the first criteria for identifying substantially identical outfalls. A summary of the contractor findings related to industrial activity at Altus is presented below (AL/OEBE, 1993:2-1).

Category (i) - Subchapter N: There are no facilities onsite that are subject to storm water effluent limitations guidelines, new source performance standards, or toxic pollutant effluent standards under 40 CFR subchapter N (parts 402 through 699).

Category (ii) - Manufacturing: There are no manufacturing activities at Altus AFB.

Category (iii) - Mineral Industry: There are no mining activities at Altus AFB.

Category (iv) - Hazardous Waste Treatment, Storage, or Disposal: To be considered a hazardous waste storage site under category (iv) of the storm water

regulations, a facility must either be operating under interim status or under a permit pursuant to subtitle C of the Resource Conservation and Recovery Act (RCRA).

There is one facility at Altus AFB operating under interim status, Part A, of RCRA (Building 451). A new enclosed facility (Building 502) will replace 451. The new facility will not be operating under interim status or under a permit pursuant to subtitle C of RCRA and, therefore, is not considered industrial under the regulations.

Category (v) - Landfills and Land Disposal: Currently there are no active landfills at Altus AFB. The sanitary refuse is removed and disposed of off-base. Also considered under category (v) are past material disposal sites identified and evaluated as part of the Installation Restoration Program (IRP). The IRP is conducted in accordance with the National Contingency Plan and requirements outlined in the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and Superfund Amendments and Reauthorization Act (SARA). Fifteen sites were identified at Altus AFB as part of the IRP. These sites include:

1. Aircraft Washrack Pond (Site WP-01);
2. AGE Washrack Pond (Site WP-02);
3. Fire Protection Training Area No.3 (Site FT-03);
4. Landfill 3/POL Sludge Burial (Site LF-04);
5. Fire Protection Training Area No. 2 (Site FT-05);
6. Fire Protection Training Area No. 1 (Site FT-06);
7. Fire Protection Training Area No. 4 (Site FT-07);
8. Landfill 1 (Site LF-08);
9. Landfill 2 (Site LF-09);
10. Service Station (Site SS-10);
11. Underground Storage Tanks (ST-11);
12. Auto Hobby Shop (ST-12);
13. Aircraft Parking Apron (Site SS-13);
14. Landfill/POL Sludge Burial (LF-14); and
15. POL Sludge Burial (WP-15). (AL/OEBE, 1993:2-4)

Sites SS-10 and ST-12 are not associated with any of the 11 categories and, therefore, are not industrial. Sites FT-06, LF-08, and ST-11 have no potential for environmental contamination and "no further action" was recommended by the environmental assessment. Decision documents for site closeout were submitted 24 January 1992. Therefore, there are ten sites remaining to be considered under category (v). These include: WP-01, WP-02, FT-03, LF-04, FT-05, ST-07, LF-09, SS-13, LF-14, and WP-15.

Category (vi) - Recycling: The Morale, Welfare, and Recreation (MWR) Squadron operates a metal recycling yard for wholesale distribution (Building 968). This activity corresponds to an SIC code of 5093 (scrap and waste materials) and is considered industrial.

Category (vii) - Steam Electric Generating: There are no steam electric generating facilities at Altus AFB.

Category (viii) - Transportation: The industrial activities of a facility covered under category (viii) are specifically limited to facilities which have vehicle maintenance shops, material handling facilities, equipment cleaning operations or airport deicing operations. The operation and maintenance activities of aircraft at Altus AFB correspond to SIC code 4581. This activity includes the operation and maintenance of the trucks used to refuel the aircraft, as well as the vehicles used to handle the material transported by air. The contractor included material handling facilities in the report, because it is the EPA's intent to include them in the regulations. Fire protection training areas were included as industrial areas under

category (viii), though they were not specifically mentioned in the storm water regulations, because this activity is closely connected with the primary mission of Altus AFB.

Category (ix) - Sewage Treatment: Altus AFB has no sewage treatment facility. The sanitary wastewater flows to and is treated at a regional facility.

Category (x) - Construction: NPDES permits are to be obtained 90 days prior to the commencement of construction activities and are regulated by state and local authorities. Due to the limited duration and seasonality of construction activities, they will not require submission of quantitative data under a general permit. Therefore, category (x) was not in the report.

Category (xi) - Commercial and Finished-Product Manufacturing: Category (xi) differs from category (ii), because industries under category (xi) do not normally store raw materials, products, waste products, or by-products where they can be exposed to storm water. As with category (ii), no finished-product manufacturing activities occur at Altus AFB.

A summary of the industrial activities at Altus AFB is presented in Table 11. The table presents the building/area number, building/area/shop name, industrial activity, and 40 CFR 122.26(b)(14) category. The areas of industrial activity were identified by the AL/OEBE contractor using a site survey, discussion with Air Force personnel, and a document review.

Table 11

Summary of Industrial Activities at Altus AFB as Defined in 40 CFR 122.26(b)(14)
(AL/OEBE, 1993:2-8)

<u>Building Number</u>	<u>Building/Area/Shop Name</u>	<u>Industrial Activity</u>	<u>Category</u>
228	Maintenance Shop	Aircraft Maintenance	viii
282	Wheel and Tire Shop	Aircraft Maintenance	viii
285	Pneudraulics	Aircraft Maintenance	viii
291	Corrosion Control	Aircraft Maintenance	viii
292	Accessory Repair	Aircraft Maintenance	viii
296	Propulsion Shop	Aircraft Maintenance	viii
298	Jet Engine Test Cell	Aircraft Maintenance	viii
323	Instrument Shop	Aircraft Maintenance	viii
330	Battery Shop	Aircraft Maintenance	viii
353	Vehicle Maintenance Shop	Vehicle Maintenance	viii
376	Refueling Truck Maintenance	Vehicle Maintenance	viii
378	Diesel Fuel Storage	Vehicle Fuel Storage	viii
379	Jet Fuel Storage	Aircraft Fuel Storage	viii
380	Jet Fuel Storage	Aircraft Fuel Storage	viii
381	Jet Fuel Storage	Aircraft Fuel Storage	viii
392	Refueling Vehicle Maintenance	Vehicle Maintenance	viii
402	Aircraft Washrack	Aircraft Cleaning	viii
424	Wheel and Tire Shop	Aircraft Maintenance	viii
435	Jack Maintenance	Aircraft Maintenance	viii
450	Non-Destructive Inspection	Aircraft Maintenance	viii
451	Hazardous Waste Storage	RCRA Permitted Storage Facility	iv
506	AGE Maintenance Shop	Aircraft Support Equipment Maintenance	viii
509	Refurbishing Hanger	Aircraft Maintenance	viii
510	Refurbishing Hanger	Aircraft Maintenance	viii
515	Fuel Cell	Aircraft Maintenance	viii
518	Fuel Cell	Aircraft Maintenance	viii
523	Phase Dock	Aircraft Maintenance	viii
553	Fuel Pump Station	Aircraft Refueling	viii
554	Jet Fuel Storage	Aircraft Fuel Storage	viii

Table 11 (cont.)

Summary of Industrial Activities at Altus AFB as Defined in 40 CFR 122.26(b)(14)

<u>Building Number</u>	<u>Building/Area/Shop Name</u>	<u>Industrial Activity</u>	<u>Category</u>
557	Jet Fuel Storage	Aircraft Fuel Storage	viii
564	Fuel Loading Station	Aircraft Refueling	viii
565	Fuel Loading Station	Aircraft Refueling	viii
968	MWR Metals Recycling	Recycling	vi
WP01	Aircraft Washrack		
	Pond	Waste Disposal	v
WP02	AGE Washrack Pond	Waste Disposal	v
FT03	Fire Protection		
	Training Area 3	Waste Disposal	v
LF04	Landfill 3/POL		
	Sludge Burial	Waste Disposal	v
FT05	Fire Protection		
	Training Area 2	Waste Disposal	v
FT07	Fire Protection		
	Training Area 4	Waste Disposal	v
LF09	Landfill 2	Waste Disposal	v
SS13	Aircraft Parking	Waste Disposal/	
	Apron	Aircraft Fueling	v/viii
LF14	Landfill/POL		
	Sludge Burial	Waste Disposal	v
WP15	POL Sludge Burial	Waste Disposal	v
—	Apron	Deicing/Refueling	viii
—	Runway	Deicing	viii

Storm water runoff that does not infiltrate into the ground or enter into surface storage, exits a watershed through a single outfall. If there are industrial areas within a watershed, the associated outfall is subject to the current NPDES storm water regulations. Following an investigation to identify outfall locations, watershed boundaries, and industrial areas, the AL/OEBE contract established a total of five outfalls which contain some form of industrial activity. These industrial activities as

noted previously in Table 11, were consolidated into six categories to facilitate the comparison of industrial activities within each of the five outfalls. The results of this comparison are summarized in Table 12.

Table 12
Industrial Activities Within Each Outfall

Outfall	A	B	C	D	E	F
001	X	X	X	X	X	--
002	X	X	X	X	--	X
003	X	--	X	--	--	--
004	--	X	--	X	X	--
005	--	--	X	--	--	--

Key:

A = Aircraft Maintenance/Washing

B = Aircraft Fuel Storage/Distribution/Refueling

C = Aircraft Support Equipment/Vehicle Maintenance

D = Landfill/Land Disposal

E = Deicing

F = Recycling

Flow Characteristics

Drainage area and estimated runoff coefficient are two variables of concern related to flow characteristics of an outfall. Altus AFB covers approximately 2,500

acres. The following sections discuss how the drainage area and runoff coefficient were estimated for each outfall.

Drainage Area. As previously stated, there are a total of five outfalls, that contain some form of industrial activity, within the Altus AFB drainage system. The boundaries of the five watersheds were identified by the AL/OEBE contractor using Tab G-3, Storm Drainage System - Master Plan drawings, 200-scale photo-based topographic drawings, and field investigation. The contractor modified the Tab G-3 to include the outfall location and boundary of each of the five watersheds. The authors used this modified Tab G-3 to calculate the drainage area of the five watersheds. The total drainage area within each watershed was determined by planimetry of the watershed boundaries delineated on the modified Tab G-3. As part of the Base Comprehensive Plan, Tab D-1, Existing Land Use, identifies the location of twelve land use categories on Altus AFB. The categories are: airfield, aircraft operational maintenance, industrial, administrative, community (commercial), community (service), medical, housing (accompanied), housing (unaccompanied), outdoor recreation, open space, and water. In order to correlate the twelve categories to a runoff coefficient and the mathematical models introduced later in this chapter, the categories were combined into four groups: industrial, commercial, residential, and nonurban. The groups are identified in Table 13.

Table 13

Land Use Groups

Industrial	Commercial	Residential	Nonurban
- Airfield	- Community (Commercial)	- Housing (Accompanied)	- Outdoor Recreation
- Aircraft Operational Maintenance	- Community (Service)	- Housing (Unaccompanied)	- Open Space
- Industrial	- Medical		- Water

The total area was determined for each land group within a watershed by using a planimeter and geometric calculation. Measurements were made on a Tab D-1 map modified to include the five watershed boundaries. The results of these measurements are listed in Table 14.

Table 14

Land Use per Outfall in Acres

Outfall	Industrial	Commercial	Nonurban	Total
001	485.62	3.72	415.92	905.3
002	22.56	2.39	2.08	27.0
003	34.14	--	--	34.1
004	216.75	4.50	605.60	826.7
005	0.2	--	--	0.2

Note: There are no residential areas contained within any of the five outfalls.

Runoff Coefficient (Rv). Runoff coefficients represent the percentage of the total volume of runoff to the total volume of rainfall (USEPA, 1992a:56). Storm

water runoff is a residual after losses to surface storage and infiltration are subtracted (Imhoff, 1989:22). Runoff coefficients consider the type and slope of the ground surface, intensity of the rainfall, and the infiltration rate of runoff into the soil (USEPA, 1992c:5-15). There are several sources that may be used to obtain an R_v value, these include actual field measurements, relevant hydrological studies, average values published in civil engineering reference manuals, and the EPA's Storm Water Sampling Guidance Document. Unless actual field measurements are available at a site, the latter two sources must be used to obtain R_v values for a drainage area. The coefficients listed in Table 15 are approximations based on the EPA's findings.

Table 15

Typical R_v values for 5- to 10-Year Frequency
Design Storms (USEPA, 1992a:57)

<u>Land Use</u>	<u>R_v</u>
Business	
- Downtown areas	0.70-0.95
- Neighborhood areas	0.50-0.70
Residential	
- Single-family areas	0.30-0.50
- Multiunits (detached)	0.40-0.60
- Multiunits (attached)	0.60-0.75
Residential (suburban)	0.25-0.40
Apartment dwelling areas	0.50-0.70
Industrial	
- Light areas	0.50-0.80
- Heavy areas	0.60-0.90
Parks and cemeteries	0.10-0.25
Playgrounds	0.20-0.35
Unimproved areas	0.10-0.30

The volume of runoff within a watershed will vary during a storm event. At the start of precipitation, the intensity of rainfall is usually less than the rate at which water is stored. As surface storage becomes filled and the soil and vegetative cover becomes saturated, the total runoff volume will approach total rainfall volume (Wanielista, 1990:79).

Surface storage is a combination of depression storage and interception storage. Depression storage occurs when runoff is held on the ground surface forming ponds and water films. Intercepted storage occurs when water adheres to the surface of plants. In urban areas with ten percent foliage, it is estimated that 0.1 inch of water is intercepted during the first hour of a storm (Wanielista, 1990:88). Surface storage is site specific and occurs on both pervious and impervious surfaces.

Infiltration is the entry of runoff into the ground. The rate and quantity of water that infiltrates into the ground is dependent on soil type, soil moisture, ground cover, drainage conditions, depth of water table, and intensity and volume of precipitation (Wanielista, 1990:76). As the intensity and duration of a storm increases, soil and vegetative cover become saturated, resulting in a decrease in the infiltration rate.

The decrease in infiltration rate is important as it relates to the range of runoff coefficient values listed in Table 15. The runoff coefficient for a particular land use can vary with soil moisture and the period of time and volume of rainfall. The coefficients listed in Table 15 are applicable for 5- to 10-year storms and were originally developed when many streets were uncurbed and drainage was conveyed in

roadside swales. Thus, conservative designs require a higher value of the runoff coefficient (Wanielista, 1990:226). An increased runoff coefficient value would be required to account for greater than a 10-yr storm and the improved conveyances present in today's urban watersheds.

Based on the previous discussion, a conservative approach was taken in the designation of runoff coefficients for the various land uses at Altus AFB. Table 16 summarizes the Rv values for each land use and outfall.

Table 16

Runoff Coefficient per Land Use

Outfall	Industrial	Commercial	Nonurban
001	.90	.95	.22
002	.90	.90	.17
003	.90	--	--
004	.90	.95	.22
005	.90	--	--

Calculation of Average Runoff Coefficient (Rv). The average runoff coefficient can be estimated for a watershed that has multiple land uses by weighting the coefficients based on their proportion of the total area (USEPA, 1992a:56). The equation used for this calculation was:

$$\text{Estimated Average Rv} = \frac{(\text{Area A})(\text{Rv A}) + (\text{Area B})(\text{Rv B}) + \dots + (\text{Area n})(\text{Rv n})}{\text{Area A} + \text{Area B} + \dots + \text{Area n}}$$

The estimated average runoff coefficient was calculated for each outfall. The results are summarized in Table 17.

Table 17
Estimated Average Runoff Coefficients

Outfall	Estimated Rv
001	0.58
002	0.85
003	0.90
004	0.40
005	0.90

Storm Water and Material Management Practices

Material management practices include structural and non-structural practices that are designed to limit the contact of materials with precipitation and/or reduce the volume of runoff that exits the facility at an outfall. The Air Force was required to identify the storm water and material management practices currently used at each of the 133 bases included in the AF group application. The Part 1 data, submitted to the EPA, served as the primary source for identifying the management practices currently employed at Altus AFB.

The storm water management practices used for activities at Altus AFB are listed below. Table 18 contains a summary of the storm water management practices

conducted within each outfall. A narrative describing each category is presented following Table 18.

Table 18
Storm Water Management Practices

Outfall	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
001	X	X			X	X	X	X			X	X				X
002	X	X			X	X	X	X		X						
003	X	X			X	X	X	X		X						
004	X	X			X	X	X	X		X	X	X				
005	X	X			X	X	X	X		X						

Key:

A = quarterly/historical monitoring of surface runoff
 B = hazardous waste management plans
 C = covered material storage
 D = POL areas and washracks connected to oil/water separators or sanitary sewers
 E = spill prevention and response plan
 F = ECAMP
 G = hazardous waste minimization plans
 H = Installation Restoration Program
 I = UST spill/overfill protection
 J = dikes/berms
 K = grass swales
 L = porous pavement
 M = wooden pallets
 N = absorbent pads
 O = horizontal placement of drums
 P = secondary containment (diking, weirs, floating booms)

The definitions provided below were obtained from the AF Part 1 group application submitted to the EPA in June 1992. The categories are storm water management activities that are used for both flying and vehicle activities at Altus AFB (AFCEE, 1992).

Quarterly/historical monitoring of surface run-off by base. Installations are required by regulation to identify all potential sources of environmental contamination and to implement a monitoring program designed to identify background levels and when problems occur.

Hazardous waste management plans. Hazardous waste management plans are required for each installation to ensure that personnel are properly trained to handle, transport, treat, store, and dispose of hazardous waste. The plan's main purpose is to ensure that everyone knows what procedures to follow when disposing of hazardous waste on the facility.

Covered material storage. Hazardous material storage is often in warehouses and under cover with a system of containment trenches to intercept wastes which may escape the storage containers.

POL areas and washracks connected to oil/water separators or sanitary sewers. POL areas and/or washracks are connected to oil/water separators prior to discharging to the sanitary sewer system.

Spill prevention and response plan. Each installation is required to have a spill prevention and response (SPR) plan which in turn requires maintaining spill cleanup material onhand. Plans are periodically exercised. The SPR plans also

include training of SPR team members in hazardous materials and waste cleanup, by procedures such as the cleanup of small spills with absorbent pads. These plans are reviewed annually and must be updated every three years.

Environmental Compliance Assessment and Management Program

(ECAMP). Under AFR 19-16 (ECAMP), each base must conduct inspections. An internal environmental inspection is performed annually and an external inspection occurs once every three years. These inspections target the ten protocol areas of: air emissions, POL, hazardous materials, hazardous wastes, natural/cultural resources, water quality, pesticides, environmental noise, solid waste, and special programs (i.e., PCBs, asbestos, radon). External inspections involve a group of personnel (approximately 10 individuals) who spend a week at an installation and concentrate on a protocol, inspecting compliance for every applicable federal, state, local, and Air Force regulation.

Hazardous waste minimization plans. Bases are also required to have hazardous waste minimization plans that identify alternatives to present uses of materials that result in hazardous wastes. Environmentally "safe" products such as Citrikleen and Simple Green are already being used in place of traditional solvents.

Installation Restoration Program. The Air Force IRP is a program for cleaning up past hazardous disposal sites. The IRP is the Air Force's implementation of its authority under CERCLA, Executive Order 12580, and 10 USC Sec 2701 et. seq. to remediate hazardous waste sites on its facilities.

UST spill/overfill protection. The Air Force has an aggressive underground storage tank program. This program includes the installation of spill/overfill protection.

Dikes/berms. Secondary containment practices such as earthen berms for above ground storage tanks.

Grass swales. Where concrete culverts are not available, grass or gravel swales provide channeling for storm water.

Porous pavement. Gravel or porous pavement also allows for rapid infiltration and temporary storage of runoff.

Wooden pallets. Most hazardous waste drums at satellite accumulation points are placed on wooden pallets for leak detection purposes, and have secondary containment.

Absorbent pads. Absorbent pads are a required stock item for hazardous waste storage areas and are used for the cleanup of spills and leaks. The absorbent material is then disposed of as a hazardous waste.

Horizontal placement of drums. Drums are sometimes placed horizontal to have the same effect as the plastic drum cover - no precipitation on the top of the drum.

Secondary containment (diking, weirs, floating booms). Secondary containment includes diking around hazardous waste storage areas, use of concrete pads, and the use of floating booms at outfalls to capture floating contaminants.

Significant Materials Exposed to Storm Water

This section of a petition is designed to identify activities on an installation with materials exposed to weather. The storm water regulations require a permit applicant to identify chemicals expected to be present in storm water runoff. 40 CFR 122.26(c)(1)(i)(E) designates that quantitative data of storm water samples must be collected for the following parameters:

1. any pollutant limited in an effluent guideline which the facility is subject;
2. any pollutant listed in the facility's NPDES permit for its process waste water (if the facility is operating under an existing NPDES permit);
3. oil and grease, pH, biochemical oxygen demand, chemical oxygen demand, total suspended solids, total phosphorus, total Kjeldahl nitrogen, and nitrate plus nitrite nitrogen, and
4. any chemical in Table 2F-3 of Federal Form 2F that is expected to be present in storm water runoff in concentrations greater than 10 parts per billion (ppb).

A site investigation was conducted by the AL/OEBE contractor to identify the chemicals used at Altus AFB that might be exposed to storm water. The investigation included a walk through of the site, review of documents, and discussion with Air Force personnel. The documents that were reviewed include: Hazardous Waste Management and Recoverable and Waste Petroleum Plan, Spill Prevention and Response Plan, Disaster Preparedness Operations Plan, Waste Analysis Plan, Environmental Pollution Monitoring Supplement to AFR 19-7, Water Pollution Monitoring results for 1991, and the IRP List Summary. Bioenvironmental Engineering also provided a computer disk file alphabetically listing all chemical

ingredients of products used on base. The list was compiled from the material safety data sheet (MSDS) information documented within each work center's Hazardous Material Inventory, Forms 2761. Chemicals identified in the review were screened and those that did not require quantitative data collection to meet regulatory requirements, were eliminated from further consideration. The final step in the process was to identify the chemicals by outfall, as summarized in Table 19.

Table 19
Chemicals Expected to be Present in Storm Water

Outfall	A	B	C	D	E	F	G	H	I	J	K	L	M	N
001	X	X	X	X	X	X	X	--	X	X	X	X	X	X
002	X	X	X	X	X	X	X	--	X	X	X	--	X	X
003	X	X	X	X	X	X	X	X	X	X	X	--	X	X
004	X	--	--	--	--	--	X	--	--	--	--	--	X	X
005	X	X	--	--	X	X	X	--	--	X	X	--	X	X

Key:

A = Oil and Grease

pH

BOD5

COD

TSS

Phosphorus

Kjeldahl Nitrogen

Nitrate plus Nitrite Nitrogen

B = Antimony

C = Beryllium

D = Cadmium

E = Chromium

F = Copper

G = Lead

H = Mercury

I = Nickel

J = Silver

K = Zinc

L = Phenols

M = Volatile Compounds

N = Base/Neutral Compounds

Mathematical Modeling

The purpose of this section is to present mathematical modeling techniques which might be employed to augment the information identified by the four previous sections. The objective of this section is to demonstrate how nonpoint source modeling can provide information that will support a petition to identify similarly identical outfalls.

Chapter II outlined the spectrum of mathematical modeling techniques available to predict nonpoint source pollution resulting from storm water runoff. In deciding which model is most appropriate to apply, it is important to consider the objectives of the modeling effort. Models may be used to:

1. characterize runoff quantity and quality as to temporal and spatial detail, such as concentration/load ranges,
2. provide input to a receiving water quality analysis,
3. determine effects, magnitudes, locations, combinations of control options,
4. perform frequency analysis on quality parameters to determine return periods of concentration, or
5. provide input into cost benefit analysis. (USEPA, 1991b:1)

Objectives 1 and 2 characterize the magnitude of the problem, and objectives 3 through 5 are related to the analysis and solution of the problem.

Three criteria were used to select a modeling technique for this case study. First, the model was required to predict total storm load. The objective of the NPDES storm water program is to determine and control the total impact of NPS pollution on receiving bodies of water. This stipulation narrowed the selection of modeling techniques to those which could satisfy objective number 2. The second criteria was to select the simplest model which could effectively estimate storm water

quality at a planning level acceptable to the EPA. And finally, the model had to utilize data that is readily available to base-level planners.

A discussion of modeling techniques is contained in Chapter II. Based on the criteria outlined above, the potential models to use in the case study were narrowed to the EPA's "Simple Method" model and the USGS's "Nationwide Regression Equation" (NRE) models. Both techniques allow for the prediction of annual pollutant loads and are useful for water-quality management and planning. The Simple Method is presented by the EPA as a method for municipalities to predict their annual pollutant loads (USEPA, 1992c:5-14). The NRE models are described by EPA as "the best generalized regression equation currently available for urban runoff quality prediction" (USEPA, 1991b:7). The NRE models are the more complex of the two and require more detailed data to support their use.

There are two NRE models capable of predicting annual loadings, the storm-runoff-load model and the mean annual load model. The NRE mean annual load model can estimate annual loads for 10 chemical pollutants: chemical oxygen demand (COD), suspended solids (SS), dissolved solids (DS), total nitrogen (TN), total kjeldahl nitrogen (TKN), total phosphorous (TP), dissolved phosphorous (DP), copper (Cu), lead (Pb), and zinc (Zn). Two of these pollutants, dissolved solids (DS) and dissolved phosphorous (DP), are not considered within the storm water regulations. This limits the number of constituents that can be predicted to eight. The annual load model was developed to predict mean annual loads at unmonitored sites that have a drainage area in the range of 0.015 to 0.85 square miles. Using this restriction,

outfalls 001, 004, and 005 at Altus could not be evaluated, because the drainage area of these outfalls is not within the required range. The calculation of an annual pollutant loading requires the average number of storms per year producing greater than 0.05" of rainfall that have been preceded by at least six hours of dry weather to be quantified.

The NRE storm-runoff-load model can estimate for a specific storm event the loading from 11 chemical pollutants: COD, SS, DS, TN, TKN, TP, DP, cadmium (Cd), Cu, Pb and Zn. Once again, two pollutants, dissolved solids and dissolved phosphorous, are not considered within the storm water regulations, reducing the constituents which can be predicted by the model to nine. Like the annual load model, the average number of storms must be defined to calculate an annual loading. The site specific variables unique to this model which have not been previously discussed are: average storm duration, average storm intensity, mean annual nitrogen load in precipitation, and population density.

The climatological data required by both models is very difficult to obtain. Two sources were found that could provide the information. The U.S. Department of Commerce, National Climatic Data Center (NCDC), Asheville, North Carolina publishes climate data on a monthly and an annual basis for all fifty states. The Air Force has its own climatic data center, the Air Weather Service located at Scott AFB. Both sources must perform special computer database inquiries to determine the parameter values required to support the NRE models. The lead time for obtaining this data from the Air Weather Service is five months.

The complex data requirements and limited planning application of the NRE models were the key factors leading to the selection of the Simple Method as the most appropriate model to incorporate into the case study. The Simple Method met all the criteria previously outlined.

EPA Simple Method Calculation and Results. This model was developed using NURP data and is intended to be used as a decision tool at the site-planning level. Recall from Chapter II, the model equation is: $L = [(P)(P_r)(R_w)/12](C)(A)(2.72)$. The annual amount of pollutant export (L) is calculated by inputting the following site specific data: 1) rainfall depth (P) per year, 2) a correction factor (P_r) for storms that produce no runoff, 3) a runoff coefficient (R_w), 4) flow-weighted mean concentration (C) of the pollutant (mg/l) in the urban runoff, and 5) area (A) of the site in acres.

The mean annual rainfall obtained from the Altus AFB weather squadron was 24.71".

A typical value for the correction factor is 0.9 (90%) (USEPA, 1992c:5-15). This is the value used in the model calculations. The correction factor can be determined by totalling the number of storms for Altus AFB that registered greater than 0.1 inches of rainfall and dividing this value by the total number of all storms recorded during the year.

Runoff coefficients were calculated for each drainage basin using a weighted approach. Each drainage basin was subdivided into three different land use categories: commercial, industrial, and nonurban. Runoff coefficients were determined for each land use category as shown earlier in Table 16. The weighted

runoff coefficient for each drainage basin was then determined as previously discussed and is listed in Table 17.

The Simple Method requires the input of the average event mean concentration, in mg/L, of pollutant discharged for a given land use. Flow-weighted mean concentration was obtained from actual storm water sampling results from Altus AFB. This information was part of their Part 2 group permit application submittal. Concentrations for COD, total suspended solids (TSS), TN, TKN, TP, Cu, Pb, Zn, Cd, antimony (Sb), beryllium (Be), chromium (Cr), iron (Fe), nickel (Ni), silver (Ag), and mercury (Hg) were obtained for each drainage basin.

Calculation of watershed drainage areas was previously discussed, the results are summarized in Table 14. Once the aforementioned site specific information was applied to the model, the results listed in Table 20 were obtained.

Table 20

EPA Simple Method Model Results

Pollutant	Drainage Basin	P inches	Pj	Rv	C (mg/L)	A acres	L (lbs)
COD	001	27.41	0.9	0.58	36	905.3	95285.30
	002	27.41	0.9	0.85	50	27.0	5782.22
	003	27.41	0.9	0.90	45	34.1	6969.82
	004	27.41	0.9	0.40	40	826.7	66678.62
SS	001	27.41	0.9	0.58	94	905.3	248800.52
	002	27.41	0.9	0.85	120	27.0	13877.33
	003	27.41	0.9	0.90	41	34.1	6350.28
	004	27.41	0.9	0.40	82	826.7	136691.17
TN	001	27.41	0.9	0.58	0.58	905.3	1535.08
	002	27.41	0.9	0.85	0.34	27.0	39.32
	003	27.41	0.9	0.90	0.76	34.1	117.71
	004	27.41	0.9	0.40	1.71	826.7	2850.51

Notes:

** - No sample data available

n/a - Pollutant levels were below detectable levels

Table 20 (continued)

EPA Simple Method Model Results

Pollutant	Drainage Basin	P inches	Pj	Rv	C (mg/L)	A acres	L (lbs)
TKN	001	27.41	0.9	0.58	0.7	905.3	1852.69
	002	27.41	0.9	0.85	1.1	27.0	127.21
	003	27.41	0.9	0.90	1.0	34.1	154.88
	004	27.41	0.9	0.40	0.8	826.7	1333.57
TP	001	27.41	0.9	0.58	0.15	905.3	397.00
	002	27.41	0.9	0.85	0.15	27.0	17.35
	003	27.41	0.9	0.90	0.20	34.1	30.98
	004	27.41	0.9	0.40	0.17	826.7	283.38
Cu	001	27.41	0.9	0.58	<0.02	905.3	n/a
	002	27.41	0.9	0.85	<0.02	27.0	n/a
	003	27.41	0.9	0.90	<0.02	34.1	n/a
	004	27.41	0.9	0.40	**	826.7	**
Pb	001	27.41	0.9	0.58	**	905.3	**
	002	27.41	0.9	0.85	**	27.0	**
	003	27.41	0.9	0.90	**	34.1	**
	004	27.41	0.9	0.40	<.001	826.7	n/a
Zn	001	27.41	0.9	0.58	<0.05	905.3	n/a
	002	27.41	0.9	0.85	<0.05	27.0	n/a
	003	27.41	0.9	0.90	<0.05	34.1	n/a
	004	27.41	0.9	0.40	**	826.7	**
Cd	001	27.41	0.9	0.58	0.001	905.3	2.65
	002	27.41	0.9	0.85	<0.001	27.0	n/a
	003	27.41	0.9	0.90	<0.001	34.1	n/a
	004	27.41	0.9	0.40	**	826.7	**
Sb	001	27.41	0.9	0.58	<0.006	905.3	n/a
	002	27.41	0.9	0.85	0.021	27.0	2.43
	003	27.41	0.9	0.90	0.010	34.1	1.55
	004	27.41	0.9	0.40	**	826.7	**
Be	001	27.41	0.9	0.58	<0.01	905.3	n/a
	002	27.41	0.9	0.85	<0.01	27.0	n/a
	003	27.41	0.9	0.90	<0.01	34.1	n/a
	004	27.41	0.9	0.40	**	826.7	**
Cr	001	27.41	0.9	0.58	<0.05	905.3	n/a
	002	27.41	0.9	0.85	<0.05	27.0	n/a
	003	27.41	0.9	0.90	<0.05	34.1	n/a
	004	27.41	0.9	0.40	**	826.7	**
Fe	001	27.41	0.9	0.58	0.88	905.3	2329.09
	002	27.41	0.9	0.85	0.70	27.0	80.95
	003	27.41	0.9	0.90	0.36	34.1	55.76
	004	27.41	0.9	0.40	**	826.7	**
Ni	001	27.41	0.9	0.58	<0.05	905.3	n/a
	002	27.41	0.9	0.85	<0.05	27.0	n/a
	003	27.41	0.9	0.90	<0.05	34.1	n/a
	004	27.41	0.9	0.40	**	826.7	**
Ag	001	27.41	0.9	0.58	<0.005	905.3	n/a
	002	27.41	0.9	0.85	<0.005	27.0	n/a
	003	27.41	0.9	0.90	<0.005	34.1	n/a
	004	27.41	0.9	0.40	**	826.7	**
Hg	001	27.41	0.9	0.58	**	905.3	**
	002	27.41	0.9	0.85	**	27.0	**
	003	27.41	0.9	0.90	0.034	34.1	5.27
	004	27.41	0.9	0.40	**	826.7	**

Notes:

** - No sample data available

n/a - Pollutant levels were below detectable levels

As mentioned earlier, the event mean concentrations used in the Simple Method were obtained from actual field sampling results collected at Altus AFB. This fact might cause one to put more weight in the validity of the Simple Methods results. However, long-term annual comparisons are generally more important than event-based comparisons. The sampling data obtained from Altus AFB was for one storm event. There is no way to verify whether the sample results are truly representative of the watershed at Altus AFB. Factors such as seasonal variability and faulty sample collection could impact the validity of the event mean concentrations used in the Simple Methods predictions.

One fact that does support the use of the sampling results is seen when the Altus AFB sampling results are compared to the EMC's reported by other Air Force group application installations shown in Table 21.

Table 21

AF Group Application Sampling Results

(EMC range in mg/L)

Pollutant	Altus	All others
COD	36-50	10-62.5
TSS	41-120	37-319
TN	0.34-1.71	0.26-8.3
TKN	0.70-1.10	0.6-2.17
TP	0.15-0.20	0.07-0.94

Note: "All others" category is a summary of the range of values reported by six other AF group applicant bases.

As of 15 July 1993, seven bases including Altus had reported EMC's, they are: Davis-Monthan AFB, Keesler AFB, Elmendorf AFB, Minot AFB, Fairchild AFB, and Vance AFB. The comparison reveals that the range of EMC's reported by Altus AFB is consistent with the other AF installations.

Matrix Presentation

The matrices presented below were designed to address in a consolidated format the industrial activities, flow characteristics, storm water management practices, and potentially exposed materials present at Altus AFB. To satisfy the criteria introduced at the beginning of this chapter, the four areas are presented in a matrix format which can be submitted to a permit authority to petition that two outfalls are "similarly identical". Though not required by the EPA, results from the "Simple Method" storm water model are included to better quantify the relationships between two outfalls.

It is important to note that facilities are required to submit an owner/operator certification describing specific information associated with each outfall to the permitting authority. Matrix information is required only for those outfalls that the permit applicant is attempting to demonstrate are identical, not for all outfalls.

Emphasis is placed on the fact that a "less polluted watershed" can be a subset of a second watershed. For example, if outfall A contains similar hydrologic characteristics and the same potential pollutant loading for certain pollutants of concern as does outfall B, but outfall B contains additional chemicals of concern, then

only outfall B should require sampling analysis. For instance, if the entire outfall is not identical, the second "more polluted watershed" (outfall B) can be sampled as an adequate worst case representation of the two watersheds.

The conclusion drawn from the matrix presentation (Tables 22-26), is that sampling should be performed at outfall 001 as a worst case representation of outfalls 001 and 004, and that, sampling should be performed at outfall 002 as a worst case representation of outfalls 002 and 003, except for metals which should be sampled at both 002 and 003.

Table 22

Industrial Activities

Outfall	A	B	C	D	E	F
001	X	X	X	X	X	--
004	--	X	X	X	--	--
002	X	X	X	X	--	X
003	X	--	X	--	--	--

Key:

- A = Aircraft Maintenance/Washing
- B = Aircraft Fuel Storage/Distribution/Refueling
- C = Aircraft Support Equipment/Vehicle Maintenance
- D = Landfill/Land Disposal
- E = Deicing
- F = Recycling

Table 23

Summary of Flow Characteristics

Outfall	A	B
001	.58	905.3
004	.40	826.9
002	.85	27.0
003	.90	34.1

Key:

A = Estimated Average Runoff Coefficient

B = Approximate drainage area of outfall (acres)

Table 24

Storm Water Management Practices

Outfall	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
001	X	X			X	X	X	X			X	X				X
004	X	X			X	X	X	X		X	X	X				
002	X	X			X	X	X	X		X						
003	X	X			X	X	X	X		X						

Key:

A = quarterly/historical monitoring of surface runoff

B = hazardous waste management plans

C = covered material storage

D = POL areas and washracks connected
to oil/water separators or sanitary sewers

E = spill prevention and response plan

F = ECAMP

G = hazardous waste minimization plans

H = Installation Restoration Program

I = UST spill/overflow protection

J = dikes/berms

K = grass swales

L = porous pavement

M = wooden pavement

N = absorbent pads

O = horizontal placement of drums

P = secondary containment (diking, floating booms)

Table 25

Chemicals Expected to be Present in Storm Water

Outfall	A	B	C	D	E	F	G	H	I	J	K	L	M	N
001	X	X	X	X	X	X	X	--	X	X	X	X	X	X
004	X	--	--	--	--	--	X	--	--	--	--	--	X	X

002	X	X	X	X	X	X	X	--	X	X	X	--	X	X
003	X	X	X	X	X	X	X	X	X	X	X	--	X	X

Key:

A = Oil and Grease

pH

BOD5

COD

TSS

Phosphorus

Kjeldahl Nitrogen

Nitrate plus Nitrite Nitrogen

B = Antimony

C = Beryllium

D = Cadmium

E = Chromium

F = Copper

G = Lead

H = Mercury

I = Nickel

J = Silver

K = Zinc

L = Phenols

M = Volatile Compounds

N = Base/Neutral Compounds

Table 26

Simple Method Model Pollutant Loading Prediction (Lbs/Yr)

Outfall	A	B	C	D	E
001	95285.3	248800.5	397	1852.7	1535.1
004	66678.6	136691.2	283	1333.6	2850.5

002	5782.2	13877.3	17.4	127.2	39.3
003	6969.8	6350.3	31	154.9	117.7

Key:

A = COD

B = TSS

C = Phosphorus

D = Kjeldahl Nitrogen

E = Nitrate plus Nitrite Nitrogen

Simple Method Model Pollutant Loading Prediction (Lbs/Yr)
(continued)

Outfall	A	B	C	D	E	F	G	H	I	J	K
001	0	0	2.65	0	0	*	0	0	0	2329	*
004	*	*	*	*	*	0	*	*	*	*	*

002	2.43	0	0	0	0	*	0	0	0	80.9	*
003	1.55	0	0	0	0	*	0	0	0	55.8	5.27

Key:

* = not sampled

0 = below detectable levels

A = Antimony

F = Lead

K = Mercury

B = Beryllium

G = Nickel

C = Cadmium

H = Silver

D = Chromium

I = Zinc

E = Copper

J = Iron

VII. Conclusions and Recommendations for Further Study

The purpose of this research was to develop sampling guidance that will enable Air Force installations to conduct cost effective storm water sampling in accordance with NPDES permit guidelines. The research examined the management and resource issues which must be addressed to comply with the storm water regulations. This chapter provides comments on the significance of the findings. The practical implications of a case study presentation for USAF installations are also discussed. Finally, recommendations are made concerning further research based upon the results of this effort.

Conclusions

The research objectives outlined in Chapter I were achieved. First, the examination of regulatory guidelines and actual field sampling efforts identified sampling practices which are necessary to ensure NPDES permit compliance. Three alternatives were identified, based on experiences of AF group applicant bases, to accomplish the storm water data collection requirements: in-house, automatic sampler, or contractor. The case study presented in Chapter VI clearly establishes a strategy that can be used by installations to petition a permit authority to reduce long-term sampling requirements by identifying similar outfall watersheds.

Alternatives for Data Collection. In Chapter V, the three options available to the AF for storm water sampling were analyzed. The three alternatives, let sampling contracts, conduct in-house manual sampling, and conduct in-house sampling using

automatic samplers, were evaluated on the basis of equipment cost, overall cost, AF manpower requirements, and quality of results in an effort to determine the optimum option. The preferred alternative was found to be the in-house manual sampling option based on its lower overall cost, though other options may be appropriate at specific installations.

Sampling Elements. Fundamental factors were identified which should be considered in order to successfully implement an in-house manual sampling program. The following will highlight those factors.

One person can successfully collect samples at a small, easily accessible outfall. Up to three people may be required for inaccessible outfalls. It is important to note that there is no requirement for all outfalls to be sampled at the same time. In order to reduce manpower requirements, different outfalls can be sampled during different storm events.

Adequate training of personnel was found to be essential. A thorough understanding of sampling procedures was found to be critical in obtaining a representative sample.

Prior coordination with the local permit authority was found to be helpful when determining the definition of a representative storm. This coordination expanded the range of acceptable representative storms for some applicants.

Prior planning and coordination with the base weather squadron and the receiving laboratory was found to be a prerequisite in order to meet sampling time constraints. Using prelabeled sample bottles also helped in meeting time constraints.

Using a telephone recall system worked best in the mobilization of personnel. In order to further facilitate a quick response, all sampling equipment should be maintained in a state of readiness.

In order to determine conveyance flow rates, a table of water depths and corresponding flow rates should be developed for each outfall to be sampled. This will save time and effort during the actual storm event.

Quality assurance should always be in the forefront of every sampling effort. Proper sample collection will prevent the need to repeat the sampling effort and will save unnecessary lab analysis costs and lost manhours.

Last, but certainly not least, safety should always be practiced when conducting sample collection. Proper gear, including communication devices, should be used by all personnel. A first aid kit should always be considered an essential piece of sampling equipment.

Petitioning to Reduce Sampling Requirements. The case study demonstrates how the pollutant loading and hydrology of two outfalls can be compared and presented to a permit authority for determination as "similarly identical" thereby reducing sampling requirements. The case study also demonstrated how a simple mathematical model could be used to supplement outfall information in order to further substantiate a reduction in sampling requirements.

Recommendations for Further Research

The goal of this research has been to identify guidelines for the development of effective storm water compliance monitoring for the Air Force. There are five areas that could be investigated to follow up on the findings that have been previously outlined. These recommended areas should enable the Air Force to meet permit requirements and negotiate permit conditions that allow for more efficient management of NPS pollution.

Biocriteria Based Permit Requirements. Biocriteria refers to incorporating numerical and biological criteria into the NPS monitoring process. Instead of regulating NPS discharges based on numerical standards developed for continuous point sources of pollution, NPS discharge standards could be designed using criteria based on water body use. The goal would be to supplement analytical chemical data with other ecological criteria that include biological and habitat considerations. In October 1990, the U.S. General Accounting Office reported that the inconsistencies between point and nonpoint pollution measurement are hampering efforts by the NPDES permit authorities and state NPS programs to fully develop their NPS programs (U.S. GAO, 1990:46). Research is required to determine methods that state permit authorities are employing to regulate NPS pollution using biocriteria. This information would enhance the storm water programs, allowing the Air Force to be proactive in anticipating future requirements.

Training Program Evaluation. The USAF School of Aerospace Medicine, Bioenvironmental Engineering Department located at Brooks AFB, TX is responsible

for the formal training of bioenvironmental engineering personnel. A formal lesson plan has not been developed for storm water sampling or the new NPDES sampling requirements. The limited instruction related to storm water is due in part to the continued development of storm water program requirements and the lack of definitive permit requirements from state and federal permit authorities. Research is required to determine the requirements and scope of water sampling training to include a proposed lesson plan, identification of target students, and determination of the most effective teaching mode.

Civilian Storm Water Program Evaluation. Research to identify civilian "benchmark" storm water sampling programs will assist AF managers in developing efficient and innovative techniques to meet the sampling requirements of the NPS pollution control program.

Model Applications. Further research should be conducted to determine the applications of the Nationwide Regression Equation and Buildup/washoff models discussed in Chapter II. Perhaps these models could be used in the development of storm water management plans or the evaluation of Best Management Practices.

Storm Event Definition Criteria. Several Air Force bases which participated in the group application sampling process expressed concern that the representative storm event criteria is too restrictive and should be reevaluated. The frustration expressed by the bases was due to the fact that rain storm events were sampled only to find that the seasonal characteristics of the storm would not fall within the EPA's narrow "average storm event" definition. Research is required to evaluate the

application of the EPA's current storm event criteria. Investigation should include a review of permit authority guidance and the problems associated with defining an average storm event.

Appendix A: Definitions

The following definitions were obtained from the EPA Guidance Manual for the Preparation of NPDES Permit Applications for Storm Water Discharges Associated with Industrial Activity and the EPA NPDES Storm Water Sampling Guidance Document unless cited otherwise.

Acute Exposure - Exposure over a short amount of time (U.S. Council on Environmental Quality, 1989:355).

Anaerobic Conditions - This condition exists when there is a complete absence of dissolved oxygen in the medium (such as water) (Viessman and Hammer, 1985:429).

Bioenvironmental Engineering (BEE)- The base agency that provides services within the areas of: industrial hygiene surveillance; OSHA compliance; environmental monitoring; and other health related support functions (AL/OEBE, 1993:v).

Biochemical Oxygen Demand (BOD) - The quantity of oxygen consumed by microorganisms during the biodegradation of matter over a specified period of time, usually during the first 5 days. A high BOD level is usually associated with a low availability of dissolved oxygen, which is detrimental to aquatic life.

Bioconcentration - The accumulation of a substance (e.g., a chemical) in tissues of an organism (such as fish) to levels that are greater than the level in the medium (such as water) in which the organism resides (U.S. Council on Environmental Quality, 1989:357).

Chemical Oxygen Demand (COD) - Measurement of all the oxidizable matter found in a runoff sample, a portion of which could deplete dissolved oxygen in receiving waters.

Chronic exposure - Chronic exposure refers to long-term, low-level exposure which may cause latent damage that does not appear until later (U.S. Council on Environmental Quality, 1989:358).

Composite Sample - Used to determine "average" loadings or concentrations of pollutants, such samples are collected at regular time intervals, and pooled into one large sample, can be developed on time or flow rate.

Conveyance - A channel or passage which conducts or carries water including any pipe, ditch, channel, tunnel, conduit, well, or container.

Event Mean Concentration (EMC) - The average concentration of an urban pollutant measured during a storm runoff event. The EMC is calculated by flow-weighting each pollutant sample measured during a storm event (James and others, 1991:518).

Dissolved Solids (DS) - See Total Dissolved Solids (TDS).

Fecal Coliform - Minute living organisms, referred to as coliform bacteria, that originate in human or animal feces that are used as an indirect indicator of the other disease causing bacteria found in water (Viessman and Hammer, 1985:250).

First Flush - Individual sample taken during the first 30 minutes of a storm event. The pollutants in this sample can often be used as a screen for non-storm water discharges since such pollutants are flushed out of the system during the initial portion of the discharge.

Flumes - A specially shaped open channel flow section providing a change in the channel area and/or slope which results in an increased velocity and change in the level of the liquid flowing through the flume. A flume normally consists of three sections: (1) a converging section; (2) a throat section; and (3) a diverging section. The flow through the flume is a function of the liquid level at some point in the flume.

Flow-Weighted Composite Sample - Refers to a composite sample consisting of a mixture of aliquots (a discrete sample used for analysis) collected at a constant time interval, where the volume of each aliquot is proportional to the flow rate of the discharge.

Flow-Proportional Composite Sample - Combines discrete aliquots of a sample collected over time, based on the flow of the wastestream sampled. There are two methods used to collect this type of sample. One collects a constant sample volume at time intervals which vary based on stream flow. The other collects aliquots at varying volume based on stream flow, and constant time intervals.

Grab Sample - A discrete sample which is taken from a wastestream on a one-time basis with no regard to flow or time; instantaneous sample that is analyzed separately.

Heavy Metals - Chemically speaking, this term refers to metals with specific gravity greater than about 4 or 5, but more often, the term is simply used to denote metals that are toxic. This includes aluminum, arsenic, beryllium, bismuth, cadmium,

chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, strontium, thallium, tin, titanium, and zinc (Masters, 1991:114).

Leachates - The solution obtained as a result of materials being removed into solution by the percolation of a liquid through a medium (such as soil) (Wentz, 1989:317).

National Pollutant Discharge Elimination System (NPDES) - The national program for issuing modifying, revoking and reissuing, terminating, monitoring, and enforcing permits and imposing and enforcing pretreatment requirements, under Sections 307, 318, 402, and 405 of the Clean Water Act.

Nonpoint Source Pollution - Pollution that does not originate from a single point or operation. NPS pollution is generally associated with runoff water from the surface which carries with it sediment, organic material, nutrients, and toxins into receiving waters.

Oils and Grease (O&G)- Include a wide variety of organic compounds having different physical, chemical, and toxicological properties. Common sources are petroleum derivatives and fats from vegetable oil and meat processing (Viessman and Hammer, 1985:239).

Outfall - Point source where an effluent is discharged into receiving waters.

Pathogens - Disease-producing organisms that grow and multiply within the host (Masters, 1991:42).

Peak Discharge - The maximum instantaneous flow at a specific location resulting from a given storm condition (James and others, 1991:520).

pH - A number denoting the common logarithm of the reciprocal of the hydrogen ion concentration. A pH of 7.0 denotes neutrality, higher values indicate alkalinity, and lower values indicate acidity (James and others, 1991:42).

Phenols- Phenols are industrial compounds used primarily in production of synthetic polymers, pigments, and pesticides, and occur naturally in fossil fuels (Viessman and Hammer, 1985:231).

Point Source - Any discernible, confined, and discrete conveyance, including but not limited to pipe ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, vessel or other floating craft from which pollutants are or may be discharged. This term does not include return flows from irrigated waters.

Pollutant - dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt and industrial, municipal, and agricultural waste discharged into water.

Pollution - the man-made or man-induced alteration of the chemical, physical, biological, and radiological integrity of water.

Runoff Coefficient - The fraction of total rainfall that will appear at the conveyance as runoff.

States with NPDES Authority - States that have been granted by the EPA the authority to issue NPDES permits. As of March 1992, 25 states have NPDES permitting authority.

Storm Water - Storm water runoff, snow melt runoff, and surface runoff, and drainage, discharged as a result of rain, snow, or other precipitation.

Storm Water Discharge Associated with Industrial Activity - Discharge from any conveyance which is used for collecting and conveying storm water which is directly related to manufacturing processing or raw materials storage areas at an industrial plant [see 40 CFR 122.26(b)(14)].

Suspended Solids (SS) - See Total Suspended Solids (TSS).

Total Kjeldahl Nitrogen (TKN)- The total concentration of organic and ammonia nitrogen in a wastewater (Masters, 1991:126).

Total Dissolved Solids- Refers to the amount of total solids minus total suspended solids. Total solids is defined as the residue left in a drying dish after evaporation of a sample of water and subsequent drying in an oven.

Total Nitrogen- defined as nitrate plus nitrite.

Total Suspended Solids- Refers to the nonfilterable residue that is retained on a glass-fiber disk filter mesh measuring 1.2 micrometers after filtration of a sample of water or wastewater (Viessman and Hammer, 1985:242).

Toxins - Refers to poisons of biological origin (U.S. Council on Environmental Quality, 1989:374).

Turbidity - Describes the capability of light to pass through water.

Volatile Organic Compounds (VOC) - Are often used as solvents in industrial processes and are either known or suspected carcinogens or mutagens. The five most toxic are Vinyl Chloride, Tetrachloroethylene, Trichloroethylene, 1,2-Dichloroethane, and Carbon Tetrachloride (Masters, 1991:116).

Watershed - The region drained by or contributing water to a stream, lake, or other body of water (James, 1993:523).

Weir - A device used to gauge the flow rate of liquid through a channel; is essentially a dam built across an open channel over which the liquid flows, usually through some type of notch.

Appendix B: Industrial Storm Water Permit Categories

An industrial facility must fall within one of 11 categories specified in 40 CFR 122.26(b)(14)(i-xi) to be subject to the storm water permit regulations. If no activities at a facility fall into one of the 11 categories, a storm water permit is not required. The 11 categories are listed below:

- (i) facilities subject to effluent standards under 40 CFR subchapter N,
- (ii) facilities with SIC codes whose initial digits are 24 (except 2434), 26 (except 265 and 267), 28 (except 283), 29, 31, 32 (except 323), 33, 344, or 373,
- (iii) facilities with SIC codes whose initial digits are from 10 through 14,
- (iv) hazardous waste treatment/storage facilities operating under a RCRA subtitle C permit or that have been identified under CERCLA/SARA,
- (v) landfills receiving wastes from activities defined to be industrial under these regulations,
- (vi) recycling facilities with SIC codes of 5105 and 5093,
- (vii) steam electric generating facilities,
- (viii) transportation facilities with SIC codes whose initial digits are 40, 41, 42 (except 4221 - 4225), 43, 44, 45, or 5171,
- (ix) sewage treatment works with design flows of one million gallons per day or more,
- (x) construction activities disturbing 5 acres or more, and
- (xi) facilities with SIC codes whose initial digits are 20, 21, 22, 23, 2434, 25, 265, 267, 27, 283, 285, 30, 31 (except 311), 323, 34 (except 3441), 35, 36, 37 (except 373), 38, 39, and 4221-4225.

The following is a list of SIC Code groups which are referenced in the NPDES

Storm Water Regulations:

No.	Title
10	Metal Mining
12	Coal Mining
13	Oil and Gas Extraction
14	Nonmetallic Minerals, Except Fuels
20	Food and Kindred Products
21	Tobacco Products
22	Textile Mill Products
23	Apparel and Other Textile Products
24	Lumber and Wood Products
25	Furniture and Fixtures
26	Paper and Allied Products
27	Printing and Publishing
28	Chemicals and Allied Products
29	Petroleum and Coal Products
30	Rubber and Miscellaneous Plastic Products
31	Leather and Leather Products (except 311)
32	Stone, Clay, and Glass Products
33	Primary Metal Industries
34	Fabricated Metal Products
35	Industrial Machinery and Equipment
36	Electronic and Other Electric Equipment
37	Transportation Equipment
38	Instruments and Related Products
39	Miscellaneous Manufacturing Industries
40	Railroad Transportation
41	Local and Interurban Passenger Transit
42	Trucking and Warehousing
43	United States Postal Service
44	Water Transportation
45	Transportation by Air
5015	Motor Vehicle Parts, Used
5093	Scrap and Waste Materials
5171	Petroleum Bulk Stations and Terminals

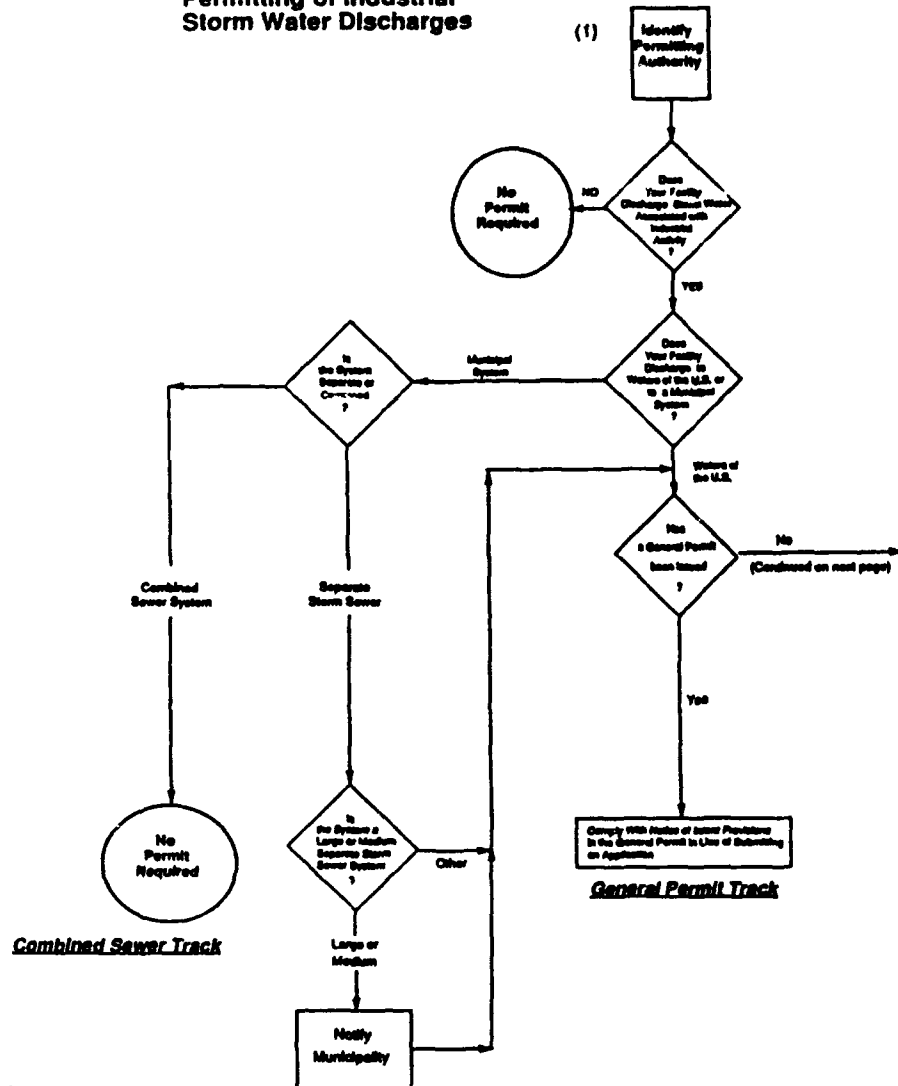
Note:

For the exact 4-digit SIC codes within each industry group number, refer to the Standard Industrial Classification Manual, 1987 Edition, U.S. Executive Office of the President, Office of Management and Budget.

Appendix C: NPDES Permitting Process Flow Diagram

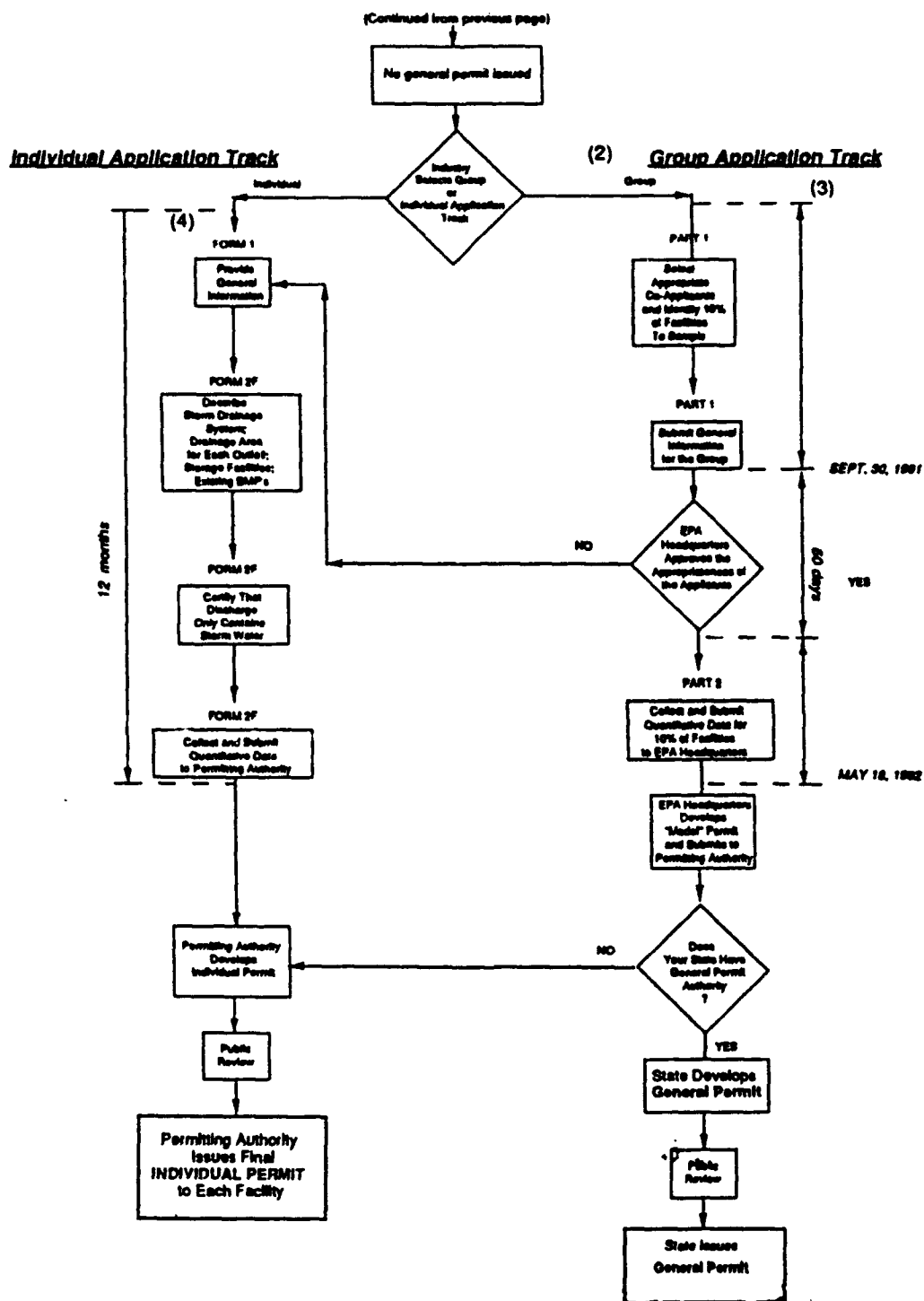
The following diagram traces the NPDES permitting process for Industrial storm water discharges (USEPA, 1991a:10-11).

**Flowchart for NPDES
Permitting of Industrial
Storm Water Discharges**



Notes:

- (1) Permitting Authority: States which have NPDES permit authority, otherwise EPA regional offices
- (2) States with NPDES permit authority can disallow participation in a group application
- (3) Time line begins at the date of publication of the final rule
- (4) Other forms may be required in addition to Forms 1 and 2F



Appendix D: Storm Water Sampling Phone Questionnaire

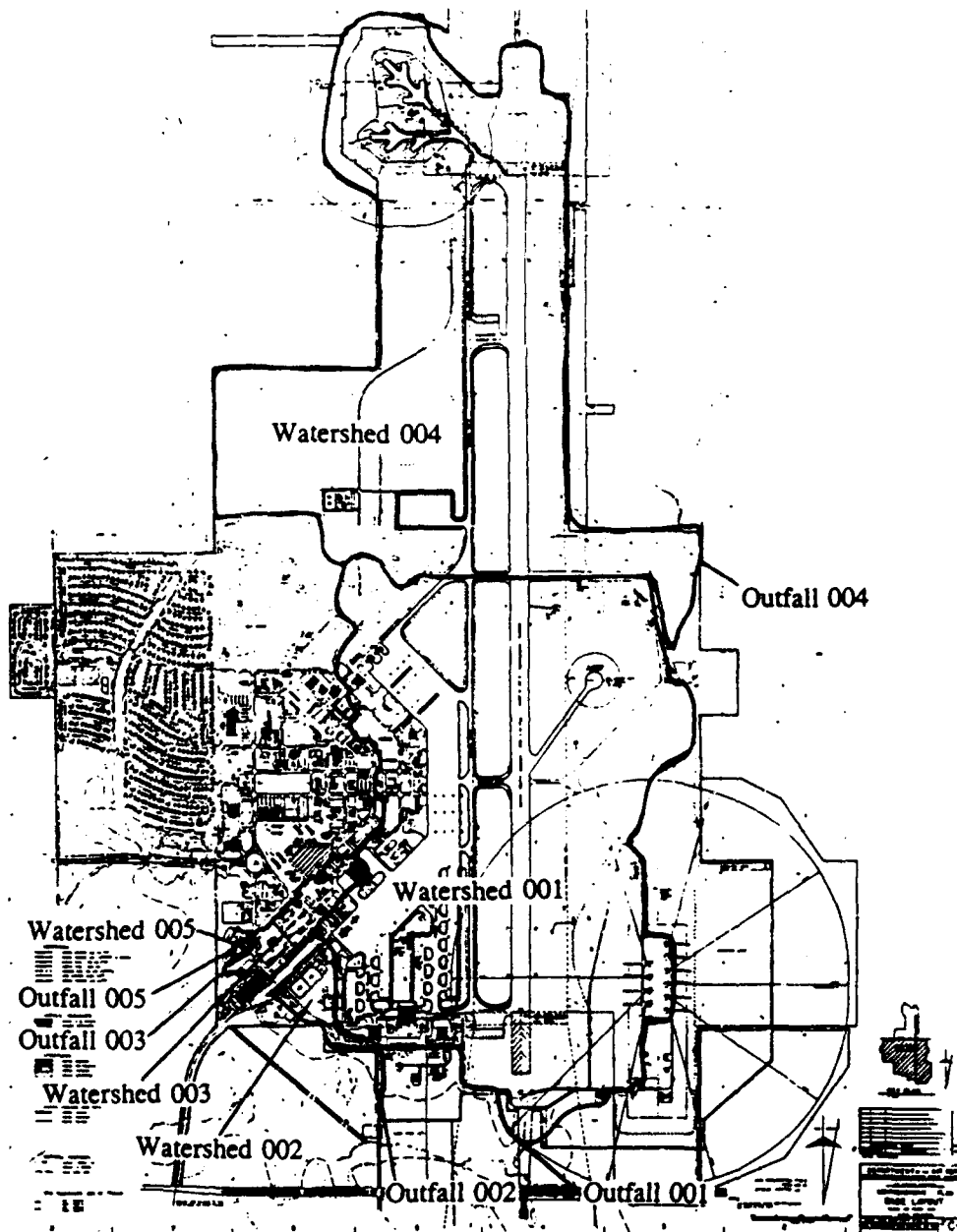
The following questions were posed to twelve Air Force bases which participated in Part II of the group permit application process. Part II required the applicants to sample outfalls which were identified in Part I of the permitting process. The purpose of the phone questionnaire was to identify problems/successes associated with storm water sampling. The questions and AF bases that were surveyed are listed below.

1. Did you have a problem collecting grab samples? If so, please explain.
2. Did you have a problem collecting composite samples? If so, please explain.
3. Did you have a problem compositing the sample? If so, please explain.
4. Did you experience Quality Assurance/Quality Control problems with the laboratory analyzing your samples? For example; replicate samples giving different values, BOD > COD, field blanks producing anomalous results, etc. If so, please explain.
5. Did you experience problems with meeting time limitations such as the constraint on sample holding time, or the time limits between sample collection and delivering it to the lab? If so, please explain.
6. What type of formal training on storm water sampling did the sampling team have? Please explain.
7. Please indicate how many personnel were required to perform the sampling and approximately how much time was required to perform the sampling?
8. Did you have a problem with manpower shortages? If so, please explain.
9. How and when were field sampling crews notified of an impending storm event?
10. Did you have a problem determining whether a sampled storm event was a representative storm for your area? If so, please explain.

11. Did you have a problem determining when to sample? If so, please explain. How was the start time of the storm event determined? Please explain.
12. Did you have a problem determining what to sample (BOD5, COD, Total Kjeldahl Nitrogen, Nitrate plus Nitrite Nitrogen, Total Phosphorus, etc.)? If so, please explain.
13. Did you have a problem determining where to sample (outfall location)? If so, please explain.
14. Did you have a problem determining flowrates of the sampled channel, stream, or other water conveyance? If so, please explain.
15. How did you determine the flowrate?
- ☐ Weir measurements
 - ☐ estimated
 - ☐ Float method (Velocity X Area of channel)
 - ☐ Bucket and Stopwatch method (Vol. of Bucket/time to fill bucket)
 - ☐ Runoff coefficient method
 - ☐ Flume measurement
 - ☐ other. Please explain.
16. Did you have problems determining if runoff in a water stream, or channel, etc, was well mixed? If so, please explain.
17. If an automatic sampler was used, did you experience problems with its performance? If so, please explain.
18. Were there additional equipment requirements, over and above what equipment the Bioenvironmental shop already had on hand, as a result of the storm water sampling task? If so, please explain.
19. Did you receive an adequate safety briefing concerning all hazards encountered during sampling? Please explain.
20. Do you feel you had the proper safety equipment? Please explain.
21. Overall, what problems did you encounter throughout the sampling process that were not mentioned above? Please explain.
22. What do you think could be improved or done differently to improve the overall sampling task? What improvements do you think could be made? Please explain.

Appendix E: Five Industrial Watersheds at Altus AFB

The following map delineates the five Altus AFB watersheds and their associated outfalls which contain industrial activities.



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The purpose of this research was to develop sampling guidance that will enable Air Force (AF) installations to conduct cost effective storm water sampling in accordance with current storm water regulations. Data on the techniques used by AF bases to obtain storm water samples for the AF group storm water permit application were collected and analyzed. This information was used to outline management and resource requirements associated with the implementation of NPDES storm water regulations. The use of in-house personnel, automatic sampling equipment, or a contractor to perform the field data collection was examined. An in-house manual approach to storm water sampling was identified as the preferred alternative. Also discussed are fundamental elements of storm water sampling which must be addressed to successfully complete the sampling process. Key elements presented include: personnel, mobilization strategy, sampling techniques, and equipment. A case study was performed using data obtained from Altus AFB. The study demonstrates how matrices and simple mathematical modeling can be used to petition a permit authority for a reduction in the number of outfalls which require sampling analysis. Of the five outfalls at Altus AFB, only three were found to be in need of sampling.

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